NASA Contractor Report 165681

LARGE PLATFORM ASSEMBLER NON-STRUCTURAL SYSTEM REQUIREMENTS

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Contract NAS1-15240
April 1981

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

Errata
7-14-81

ERRATA

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NASA Contractor Report number on the cover and COSATI page should be changed to read "<u>NASA Contractor Report 165743</u>".

Issued 7-2-81

FOREWORD

This task report contains the results of a six-month study conducted under Mod 6 to Contract NAS1-15240 for the NASA - Langley Research Center. This study evaluated the effects of requirements for the installation of non-structural systems (utilities) on the design and operation of an automated large space structure assembler previously reported in NASA CR-3131. This report summarizes the preliminary definition of utility requirements and installation concepts, assembler design implementation, and assembler operations and impacts analyses.

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Section 1

INTRODUCTION

The results of NASA-LaRC sponsored studies have indicated that efficient assembly techniques must rely heavily on automated erection concepts. A concept study has been completed which addresses the structural-kinematic operation of automatic assembly. (This study is reported in Ref. 1-1.). However, in order to provide operational functional platforms, an assessment must be made of the non-structural systems associated with platform assembly. It is the purpose of this study to assess the effects of those nonstructural systems requirements on an automated assembler.

The objectives of this task are as follows:

- Assess Non-Structural Requirements for Platforms; e.g.,
  - Advanced Science/Applications Platform
  - GEO Communication/Observation Platform
  - SPS Test Article
  - Space Operations Center

- Evaluate Effects of Inclusion of Installation of Non-Structural Features (e.g., utilities) on the Assembly Process and on Design and Operation of Assembler

- Define Special Requirements on Assembler and Platform Construction Due to the Installation of Utilities; e.g.,
  - Structural Hardpoints
  - Electrical Connectors
  - Mechanical Connectors

The overall guidelines followed in this study included the following:

- o Use Preferred Assembler Concept (Gimballed Parallelogram Assembly Machine) as Baseline Machine for Evaluating Integration of Non-Structural Requirements (see Fig. 1-1)

- o Evaluate Impacts for Assembly of both Linear and Area Trusses

- o Evaluate Impacts for use of Assembler in both Free-Flying and Shuttle-Attached Modes

- o Put Major Emphasis on Installation of Platform Utilities

- o Evaluate the following methods of Utility installation (as a minimum):
  - Installation into Half-Columns
  - Attachment of Separate Cables/Ducts to Selected Half-Columns During Column Assembly
  - Separate Installation of Utility Modules and/or Systems to the Completed Platform

The subject task was broken down into five subtasks as follows:

1. Definition of Utility Characteristics and Installation Requirements

2. Definition of Candidate Installation Concepts

3. Assembler Implementation Concept Definition and Design

4. Assembler Operations Analysis

5. Impact Assessment

The following Sections of this report describe the results of work performed on each of these tasks.

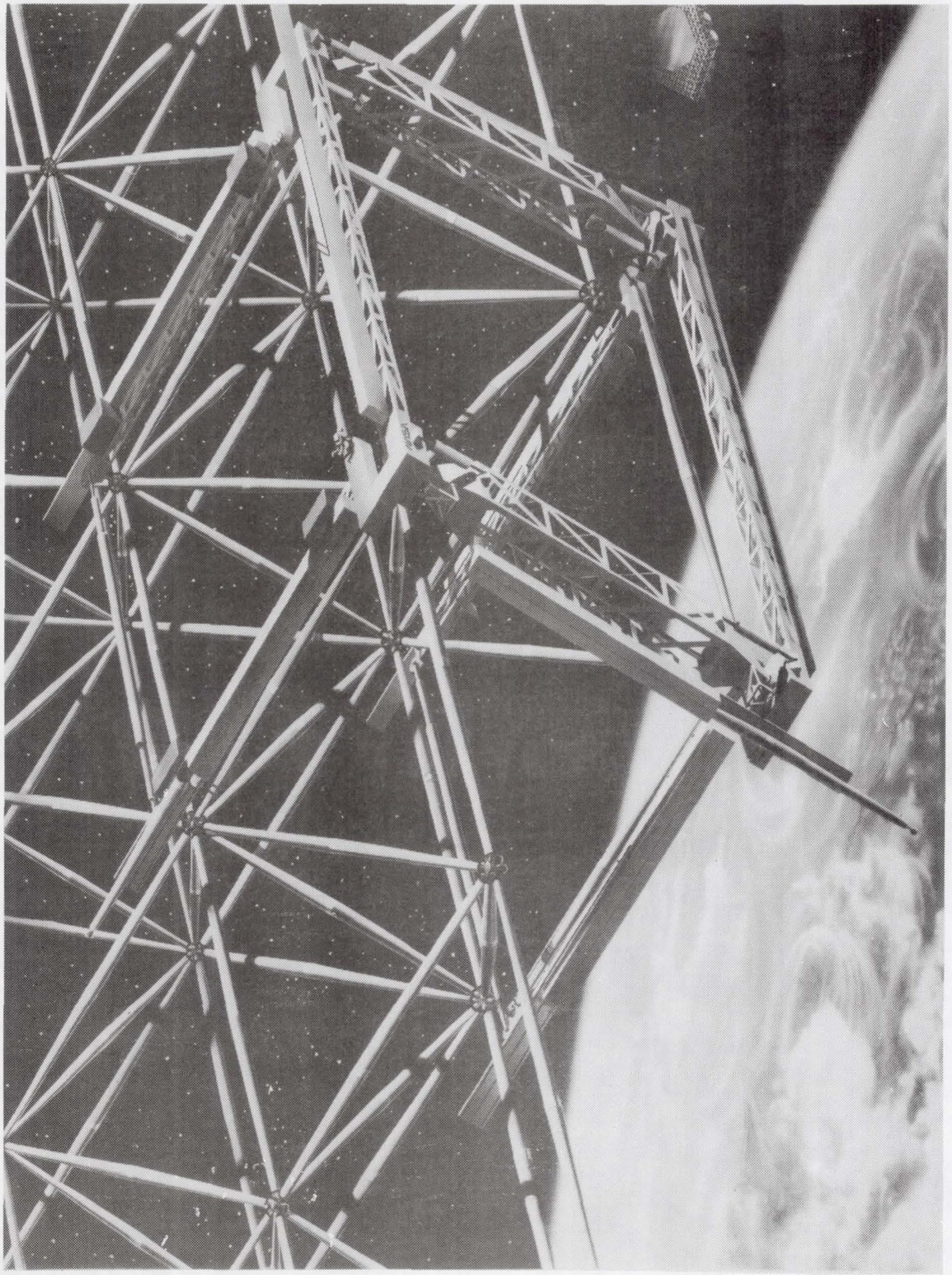


Figure 1-1 Large Space Platform - Automatic Assembly - Gimballed Parallelogram Assembler

REFERENCE

1-1 NASA CR-3131 Development of Assembly and Joint Concepts for Erectable Space Structures - Final Report.

Section 2
REQUIREMENTS DEFINITION

The utilities are defined as electric wiring and plumbing which must be attached to the platform structure during its construction, and prior to payload installation. The conceptual study is generally carried out on the basis of the 20m column platform shown in Fig. 1-1, since this configuration presents the most severe problems as a result of its large size. The results of this investigation can be made compatible with smaller column sizes, down to 5m, by appropriate scaling.

Candidate utilities considered in this task included those required for the following:

- o Electrical power distribution
- o Heat transport
- o Data transmission
- o Command and control signal transmission

As will be seen, the requirements for power transmission and heat transport dominate those for data and signal transmission. Basic requirements for the distribution of these utilities were derived using published descriptions of space platform concept designs, as exemplified by Refs 2-1 and 2-2. A summary of electrical power requirements for a variety of platforms is shown in Fig. 2-1. In general, the larger platforms require larger total power, and benefit most from high voltage distribution systems. A breakdown of utility distribution systems for the four reference platforms (Rockwell P-1, MDAC A/B, SASP and ASASP) is shown in Figs. 2-2 through 2-5. As mentioned above, it can be seen that wire sizes for power distribution are much larger than those for data and signal transmission. Therefore, attention was directed toward requirements for power and coolant distribution, and definition of a baseline set of near-term requirements and an alternative set of requirements for an advanced platform. These requirements are summarized in Figs. 2-6 and 2-7.

PLATFORM	DIRECT CURRENT LOAD	
	AVG. POWER (kW)	VOLTAGE (V)
ROCKWELL P-1	5.0 (PRIMARY) 2.0 (BACKUP)	28 (HIGH)
MDAC A/B	12.4	113-168
MDAC H	12.4	113-168
SASP – A	7.4	28
B	13.3	28
C	25.0	28
ASASP	33.3	120/30

Figure 2-1 Electrical Power Requirements

- PRIMARY POWER – 28 VDC, EIGHT NO. 4 AWG WIRES
- HIGH-VOLTAGE POWER – 130 VDC, FOUR NO. 4 AWG WIRES
- CHASSIS GROUND – ONE NO. 4 WIRE
- DATA AND COMMUNICATIONS – FOUR R6143 COAX LINES
- COMMAND AND CONTROL – FOUR NO. 12 TSP LINES
- THERMAL CONTROL – FOUR 12.54 CM DIA COOLANT LINES

Figure 2-2 Utility Distribution - Rockwell P-1 Platform

- POWER – HIGH VOLTAGE ($\sim$ 130 V) DC, 0.020-IN. FLAT CABLE OR FOUR NO. 4 WIRES

- DATA AND COMMUNICATIONS – TEN NO. 20 TSP (MULTIPLEX BUS)

- COMMAND AND CONTROL – 256 NO. 20 TSP

- THERMAL CONTROL – FOUR 1.91 CM COOLANT LINES

Figure 2-3 Utility Distribution - MDAC A/B Platform

- PRIMARY POWER – 28 VDC, 24 – NO. 3 AWG WIRES

- HIGH-VOLTAGE POWER – 120/208 VDC, FOUR NO. 12 AWG WIRES

- DATA AND COMMUNICATIONS – 9 COAX LINES
  – 36 NO. 12 TSP LINES

- THERMAL CONTROL – LOCALIZED

Figure 2-4 Utility Distribution - SASP

- PRIMARY POWER – 30 VDC, EIGHT NO. 4 AWG WIRES
- HIGH-VOLTAGE POWER – 130 VDC, FOUR NO. 4 AWG WIRES
- CHASSIS GROUND – ONE NO. 4 AWG WIRE – BUS
- DATA AND COMMUNICATIONS – FIBER OPTIC DATA LINE – 10 CHANNELS
- COMMAND AND CONTROL – FOUR NO. 12 AWG TSP LINES
- THERMAL CONTROL – LOCALIZED HEAT REJECTION SYSTEM AT EACH PAYLOAD MODULE

Figure 2-5 Utility Distribution ASASP

- POWER – ON
  - 28 VDC, EIGHT NO. 4 AWG WIRES
  - FLAT CABLE, 0.020 IN. THICK
- CHASSIS GROUND – ONE NO. 4 AWG WIRE
- DATA AND COMMUNICATIONS – FOUR R6143 COAX LINES
- COMMAND AND CONTROL – FOUR NO. 12 TSP LINES
- THERMAL CONTROL
  - PUMPED-FLUID HEAT PIPES
  - FOUR 2-CM DIA THIN-WALL STEEL TUBE

Figure 2-6 Baseline Utilities - Near-Term Platform

- POWER – THIRTEEN NO. 4 AWG WIRES (INCLUDES CHASSIS GROUND)

- DATA AND COMMUNICATIONS – 10 CHANNEL FIBER OPTIC LINE

- COMMAND AND CONTROL – FOUR NO. 12 AWG TSP LINES

- THERMAL CONTROL – LOCALIZED AT P/L MODULES

Figure 2-7 Baseline Utilities - Advanced Platform

Baseline power distribution was to be obtained in both the near-term and advanced platforms by the use of No. 4 AWG cables. The most stringent requirement for coolant distribution was that for the near-term platform, where 20mm-diameter tubing was required.

REFERENCES

2-1 K. A. Bloom, "Space Construction and Utility Distribution," LSST 1st Annual Technical Review, 7-8 Nov 79.

2-2 A. LeFever, "Space Platform Utilities Distribution Study," Final Report Draft, Contract NAS1-15322, Jan 80.

Section 3
CANDIDATE INSTALLATION CONCEPTS

The basic assembler under consideration is the gimballed parallelogram machine as described in Ref. 1-1 and shown on Fig. 1-1. The goal of this section is to define concepts to give this assembler the capability of performing the installation of utilities during construction of the platform. This installation should be as automatic as possible.

The problem of installing electric wiring is treated separately from that of the piping for the following reasons.

- The piping is usually much more rigid than electric cables and requires much larger bending radii if it can be bent at all. However, for low pressure systems, this problem can be resolved by developing special flexible tubing.

- The problems of piping coupling is somewhat different from that of electric connectors (e.g., elbow couplings).

- Piping is more likely to be local (e.g., from payload to radiators) while electric wiring may run over long distances in multi-branch networks.

It is therefore considered advisable to treat the simpler problem of electric wiring first then make use of the concepts generated for wiring installation to treat the plumbing problem.

Several candidate concepts for utilities installation on practical network configurations were defined.

These concepts fall into the following categories:

- o Column-integrated conductors
  - a. Connector integral with node joint
  - b. External column-end connectors

- o Column-attached or node-joint attached utilities (lines, tubes, bundles, ducts)
  - a. Connection integrated with node joint
  - b. Connections at junction boxes or modules attached to node joints

Various options associated with these categeories are discussed and evaluated in Section 4 of this report.

Two basic installation procedures for column-attached utilities were considered in this study:

- o Continuous dispensing from drums or reels

- o Dispensing of segmented cables from special canisters

It is anticipated also that special junction boxes will be strategically located on a number of platform node joints to permit branching as required to supply various payloads.

Utilities installation is also considered as an integral part of the platform assembly, in which case it is performed by devices mounted on the assembly machine.

Section 4
CONCEPT DESIGN DEFINITION

This section contains a discussion of specific candidate designs for implementing utilities installation with the gimballed parallelogram assembler. The discussion is divided into three parts; viz., a critique of column-integrated conductors, an evaluation of various means of electrical cable installation, and a discussion of design options for installing fluid coolant piping.

4.1 COLUMN-INTEGRATED CONDUCTORS

Column-integrated conductors consist of electrical conductors which are attached to, or bonded or fabricated into, the column structure. Optional methods of integral fabrication or attachment include use of the following:

- o Attachment of conductors to columns during column manufacture
- o Metal-matrix composite columns
- o Columns of single conductive materials
- o Layered fabrication (plated or bonded conductors on a dielectric substrate)
- o Graphite-epoxy composite columns with bonded or integrally-fabricated conductors.

The assessment performed to date have shown that there are significant draw backs associated with the use of each of these options for power transmission. The primary difficulty is the problem of making reliable electrical connections between columns. In addition, the large number of connections

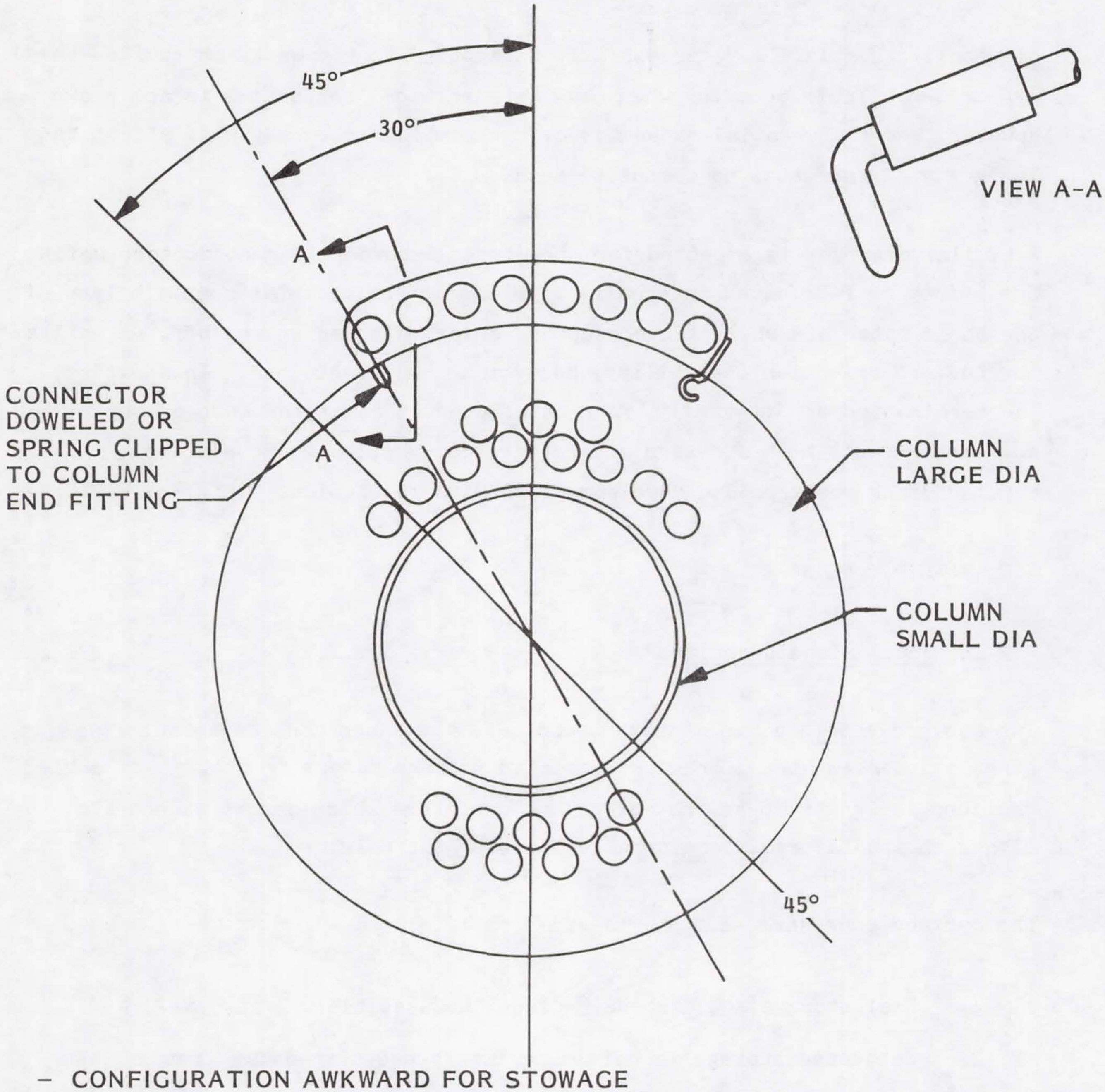
(one or more at each node joint) required with these concepts greatly reduces reliabilty and increases installation time over that for other methods.

Concept designs for column-attached power lines show that a very large increase in stacking pitch would be required for nested columns with attached power lines. This is illustrated in Fig. 4-1 where an end view of each end of a typical column is shown, with 8 No. 4 AWG wires terminating in a column-mounted connector. Such a configuration is awkward for storage, and would make nested stowage almost unpractical. If fluid coolant lines are attached in addition to the indicated power lines, the resulting configuration is not suitable for nested stowage. Furthermore, the low thermal expansion characteristics of the basic tubular column are severely compromised by the attachment of rigid tubing.

The use of metal-matrix composite columns is a potentially feasible means of providing an innately conductive structure. However, the cross-section of such a tube varies with length, thus the electrical resistance and consequently the temperature of the column would vary with length. Furthermore, the thermal expansion of the non-current-carrying columns would differ from those used for power transmission.

Columns of single conductive materials may be attractive for small structures where thermal deformation is not important. Thus structural columns of aluminum or magnesium could be utilized for power transmission over short distances. However, the losses incurred at nodal connections do not make this concept attractive for large platforms.

The use of plated or bonded conductors over a dielectric, structural tube was also considered. This includes either plated conductors, such as electroplated copper, plated aluminum, metallic spray or vapor-deposited coatings, etc., as well as conductors which are bonded to a substrate (wires, foils, etc.). The feasibility of fabricating such structures has not been firmly established; but recent developments have shown that small thicknesses



- CONFIGURATION AWKWARD FOR STOWAGE
- REQUIRES INDEXING OR SPECIAL ADAPTER FOR RMS CLAW INSTALLATION
- MULTIPLE CONNECTIONS DECREASE RELIABILITY
- MULTIPLE CONNECTIONS INCREASE ELECTRICAL LOSSES

Figure 4-1 AWG Wires in Single Connector at Peripheries of Column Ends (Specally Designed Connector)

of metallic coatings may successfully be applied to composite (graphite-epoxy) substrates. Their behavior when used as electrical conductors is not known however, and differential expansion over repeated cycles may well affect the integrity of the metal-to-composite bond.

A similar drawback is expected for structures incorporating conductors which are bonded or fabricated integrally with the composite. The compatibiliby of the basic materials while the conductors being switched on and off, as well as the basic fabrication feasibility, has yet to be established. In addition, the termination of integrally fabricated conductors at the ends of the columns presents both a design and fabrication problem which requires manufacturing research and development for its resolution.

4.2 ELECTRIC NETWORK

4.2.1 General Considerations

Two basic electric cable storage techniques are under consideration: Reel storage and segmented storage. Segmented storage refers to storage of cable sections in length up to that of column canisters which cannot exceed 17m, either in special canisters or together with the columns.

The options considered are as follows:

1. Reel storage and dispensing from the assembler. (Fig. 4-2)
2. Segmented storage in column canisters and dispensing from column assembler. (Fig. 4-3)
3. Segmented storage in separate canisters and dispensing by separate devices. (Fig. 4-4)

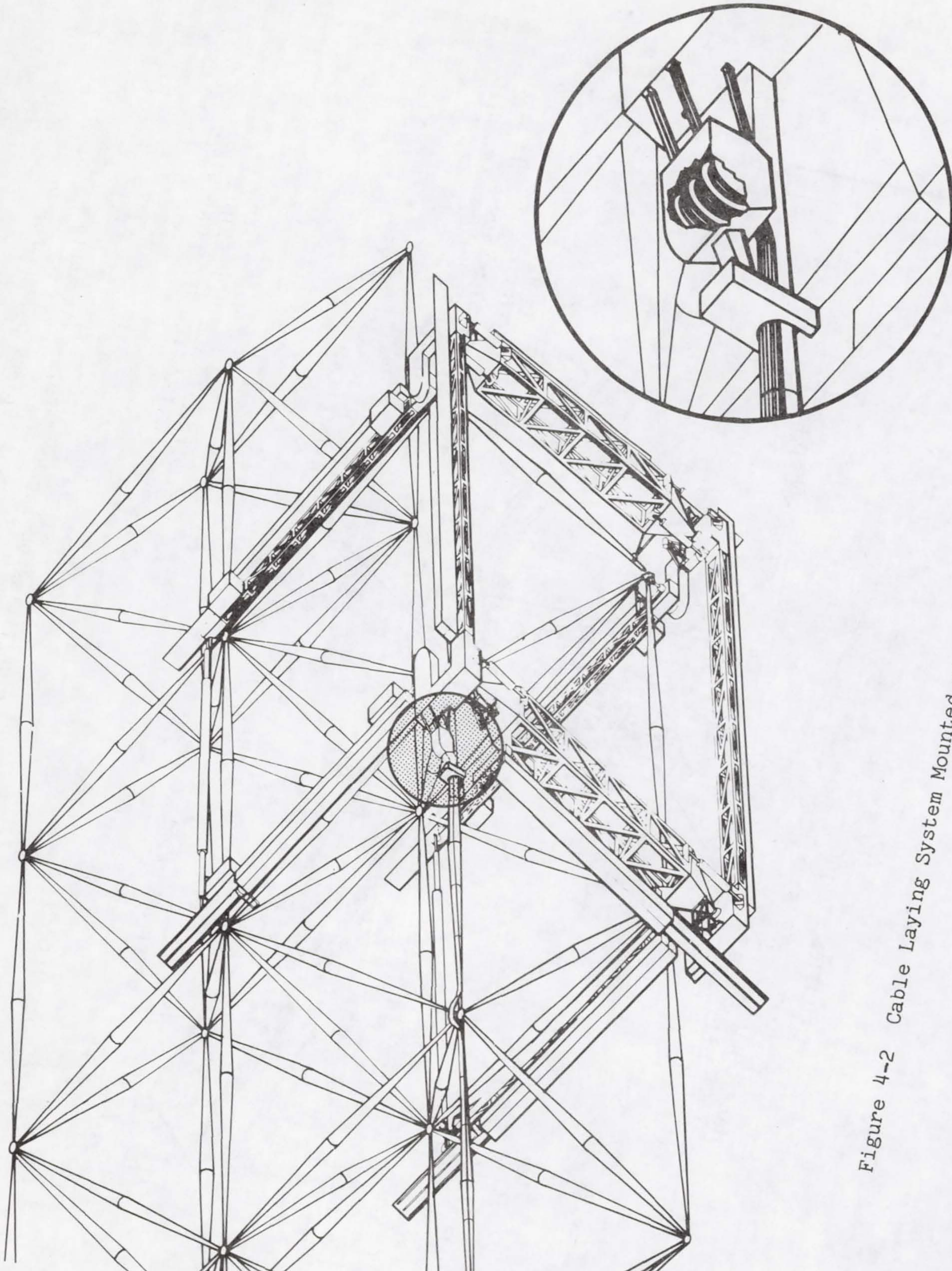


Figure 4-2 Cable Laying System Mounted on the Assmebler

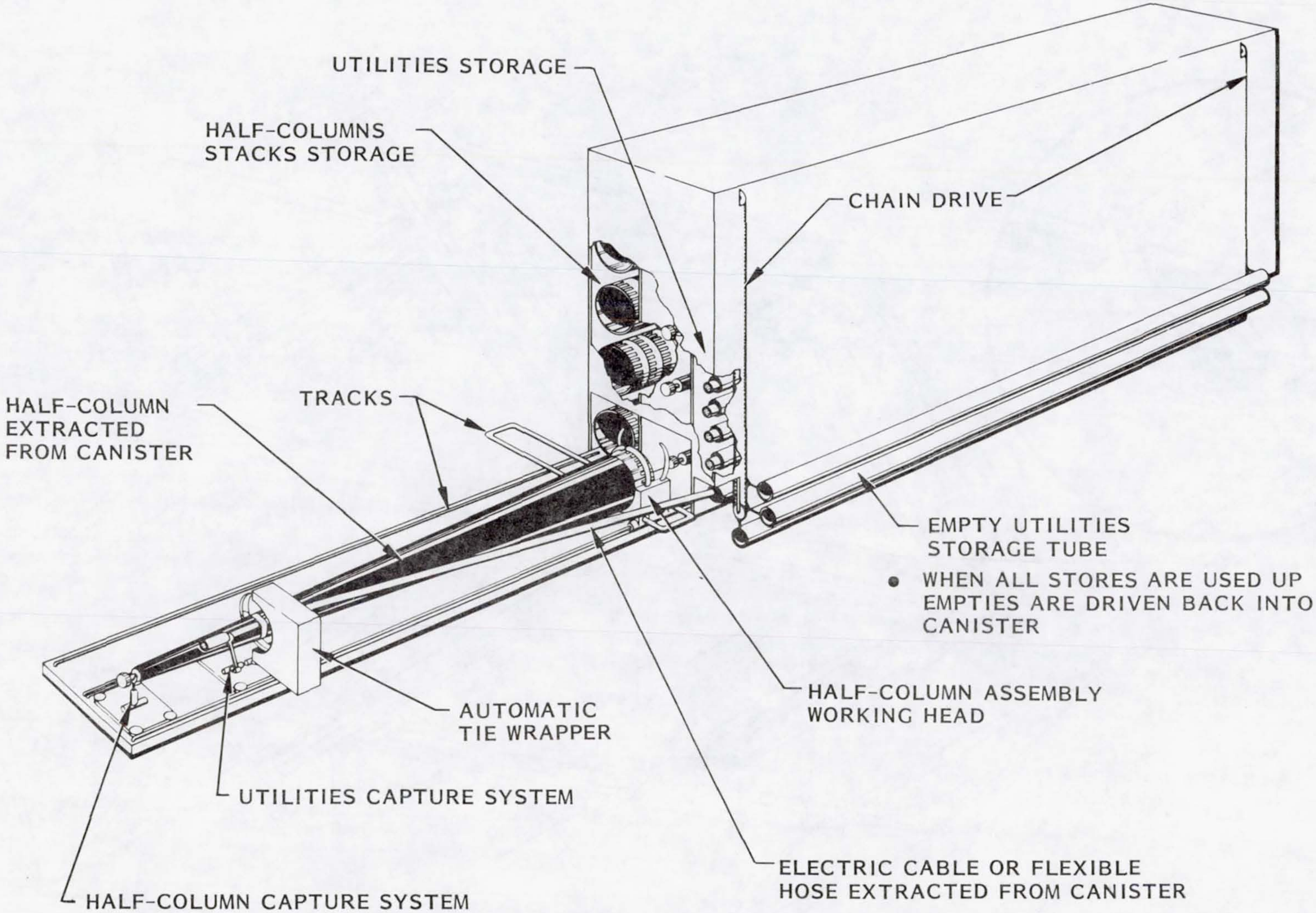


Figure 4-3 Installation of Utilities During Half-Column Assembly Using a Combined Storage Canister - Typical System for Core Columns Equipment

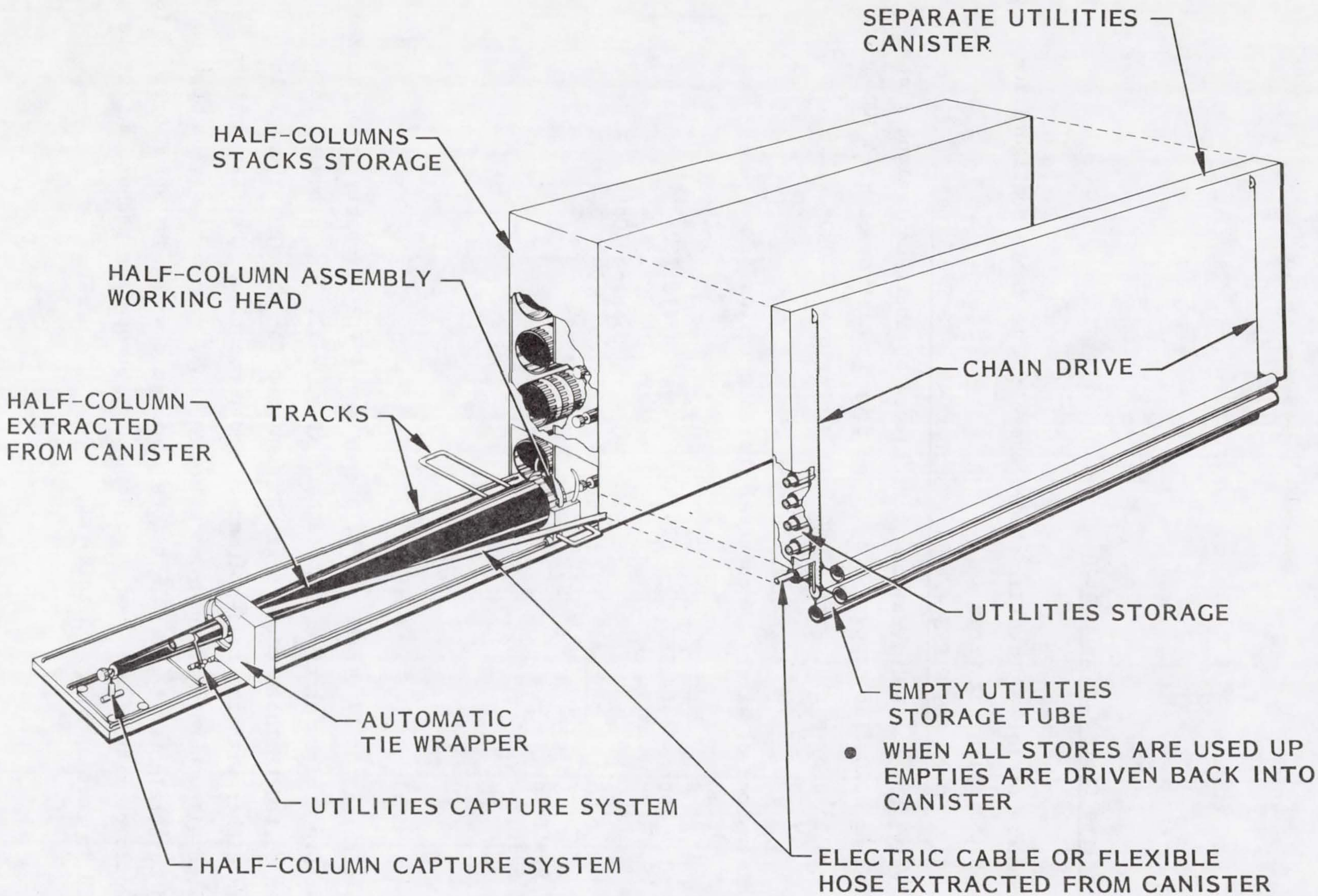


Figure 4-4 Segmented Cable Installation System with Separate Cable Canister

4.2.2 Baseline Cable Configuration

For the purpose of this conceptual study, the electric cable configuration consists of the following wires

9 #4 AWG WIRES + 4 RG 143 coax + 4 #12 TSP lines

Alternatively, the #4 AWG **wires** may be replaced by their equivalent flat cables. Using .020 flat copper, 1.63" wide plus insulation each #4 AWG wire could be replaced by a flat wire of overall dimensions: .030" x 2.5".

General dimensions of wires: Mechanical Characteristics

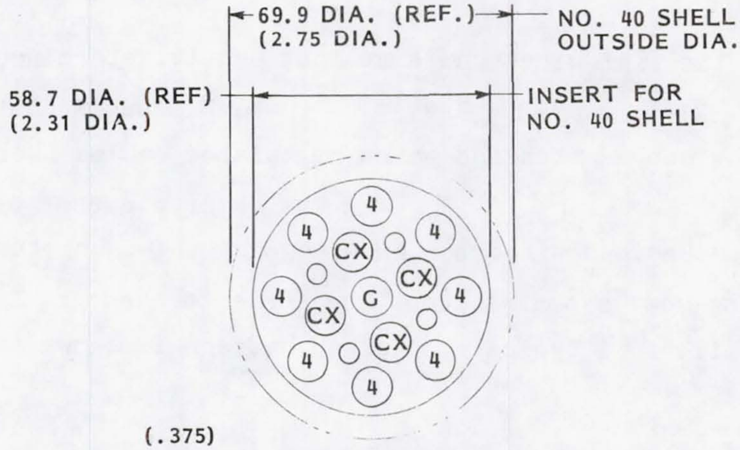
Wire Type	#4 SWG	RG-143 A/U	#12 TSP
O.D.	.28"	.33"	Copper: .081" .093"
Min Bend radius		≈6"	

A bundle consists of 17 wires: 9 #4, 4 coax and 4 #12 which may be organized either within a circular or a flat pattern (Fig. 4-5). The circular pattern is better suited to those cable segments designed for straight storage in canisters either with the half-columns or independently. The flat pattern is designed to allow bending over drums in which case, a special device must be provided to straighten the bundle before it is laid along the structure. This device would consist of a set of 3 rollers and appropriate mechanism. It is described in Section 4.2.5 of this report.

The dimensions of the flat wire bundle are most easily determined. Its width is 9 x .28 + 4 x .33 + 1 x .093 = 3.94", which assumes that the #12 cables will be provided as standard pairs of twisted cables such as MD-911-12 or similar. The outer diameter of a round wire bundle cannot be determined without a knowledge of the connector pin patterns. Assuming some symmetry about the connector center, this diameter should not exceed 1.4". A typical connector pattern is shown in Fig. 4-5.

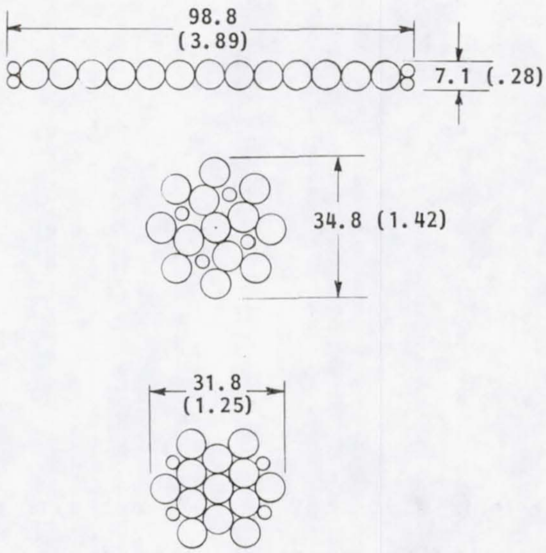
A preliminary investigation indicates that the baseline set of cables will require a #40 connector shell (Fig. 4-5) which has a diameter of 2.50". The connector nut is somewhat larger at 2.75" and special tools should be made available to the astronauts in order to perform the connection without undue difficulties. The space suit restraint on the hand mobility would make it quite impossible to turn the connector nut without special tools.

In principle, the flat bundle concept is laid out with drum or reel stowage in mind. It is adapted for laying over long distances spanning several node joints and may have multi-branches with connectors if reel stowage permits. A 1m diameter reel having a .30m core diameter will contain approximately 80m of cable in the case where only the end connectors are needed. Branching and additional connectors may reduce this length substantially but, in order to lay



(.375)
1 9.5 DIA. GROUND AT CENTER
4 9.5 DIA. CO-AX ON 0.934 DIA.
8 9.5 DIA. NO. 4 ON 1.754 DIA.
4 4.8 DIA. NO. 12
(.188)

CABLE CONNECTOR ARRANGEMENT IN
STANDARD NO. 40 SHELL



WIRE BUNDLE ARRANGEMENTS

ALL INCLUDE: 1 7.1 DIA. GROUND
4 7.1 DIA. CO-AX
8 7.1 DIA. NO. 4
4 3.1 DIA. NO. 12

Figure 4-5 Wire Bundle Arrangements

wire over distances greater than four columns, it is necessary to consider multispool stowage. Multispool stowage will make it possible to provide within a single drum canister a continuous length of cable in multiples of 80m. This technique is attractive as it reduces the number of required connections and their inherent risks of failures.

The round cable bundles are appropriate for segmented stowage in linear canisters, either in a part of the half-column canisters or in separate specialized canisters. In this case, the cables are laid straight, each one in a tubular compartment of the length of the half-column canister: 17m. These cables are to be extracted from the canister at the time of column assembly and attached to the column. They are intended for use on the core columns whenever a connection must be established between the upper and lower platform surface harnesses. The extraction and attachment mechanisms must be built into the half-column assembly system as shown in Figs. 4-5 and 406.

4.2.3 Junction Boxes

Junction boxes must be considered as part of the electrical distribution system. Junction boxes could be attached to node joints which are not payload carriers, or they could be made part of the payload attachment system. These boxes may provide some assistance in solving the problem of the short segmented cables (17m) in the case of the 20m column platform by carrying the missing 3m connection. (Fig. 4-6).

4.2.4 Mechanism to Bind Cables to Columns

The electric wire bundles cannot be allowed to float loosely about the space platform structure. It is necessary to provide some form of restraint by direct attachment to the columns. Due to the storage method (reel or segmented), it is not practical to devise an attachment system as part of the wire bundles. It is necessary to find a solution by means of an auxiliary mechanism.

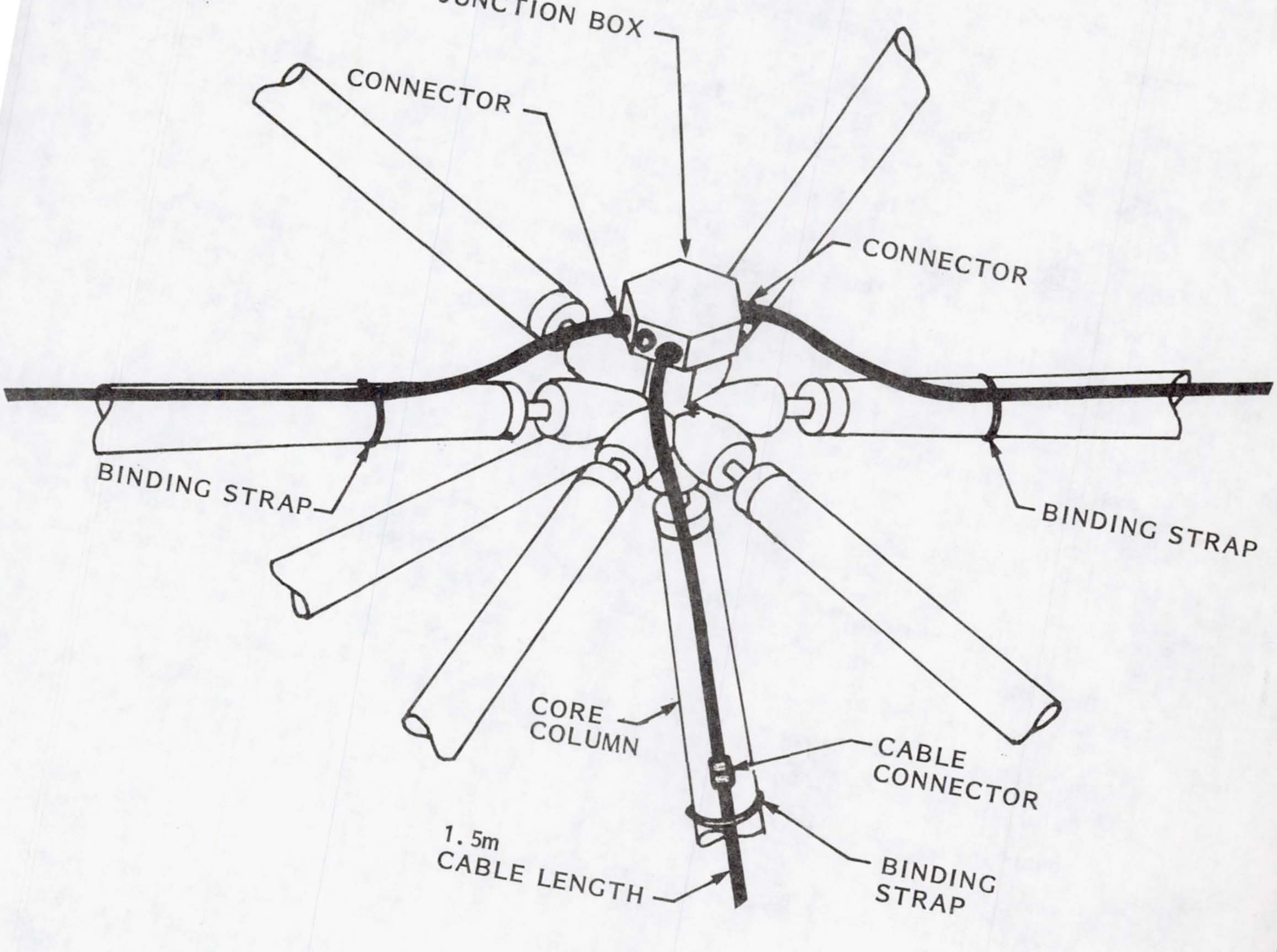


Figure 4-6 Junction Box

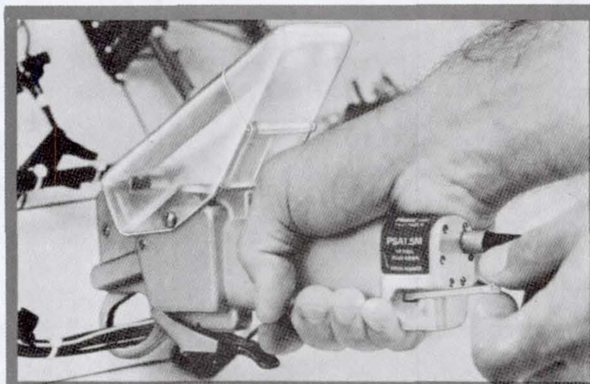
The first mechanism which came to mind is the hay bale tying machine. This well known and foolproof device can easily be adapted to operate in the space environment but the major problem is to find a tie material which will not degrade in vacuum and provide a friction force high enough to prevent knot slippage. It is believed that the conicity of the column is not a major factor because of the small taper and the cable local flexibility which would hold the tie in place.

An alternative solution would make use of standard plastic harness straps and a device capable of wrapping them around, inserting the ends and pulling them taut. Such mechanisms are commonly used on special tools, they are available from the Panduit Co. as standard tools but would require adaption to this special application. (Fig. 4-7)

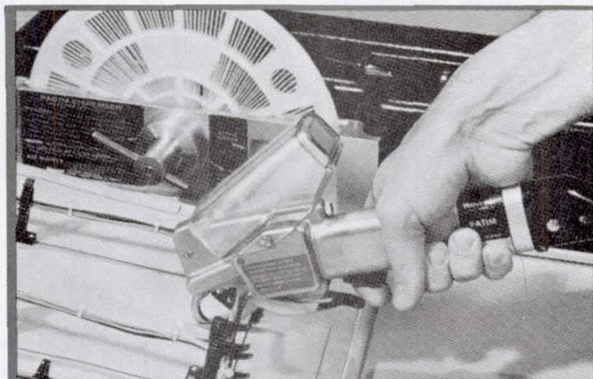
Another alternative can be considered using straps with Velcro closures which could possibly provide sufficient pressure to hold the cables in place. The mechanism required for installation of such straps can easily be derived from the systems discussed above.

4.2.5 Straightening of Spooled Cables

In laying flat cables which have been tightly wound over a drum or reel, a problem exists because of the curvature generated by this mode of storage. It is necessary to uncoil the cable while paying it off the reel so that it will lay parallel to the column without residual strain. For this purpose, the cable should be drawn from the reel by a system of rollers which will simultaneously uncoil it and give it a cross curvature to assist in the binding operation. An appropriate mechanism is shown on Fig. 4-8 and discussed further below.



PSA Semi-Automatic Installation Tools. Install hand-fed cable ties; automatically tension and cut them off flush. Two available tools: PSA1M for up to .82" bundle dia.; PSA1.5M for up to 1.30" bundle dia. Tools leased from Panduit. Cable ties sold only through Authorized Panduit Distributors.



PAT1M Fully Automatic Installation Tool. Pneumatically installs, tensions, and cuts off flush cable ties all in less than 1 sec. Installs PLT1M-MD Miniature cable ties up to .82" bundle dia. Tool leased from Panduit. Cable ties sold only through Authorized Panduit Distributors.

Figure 4-7 Panduit Strap Installation Tools

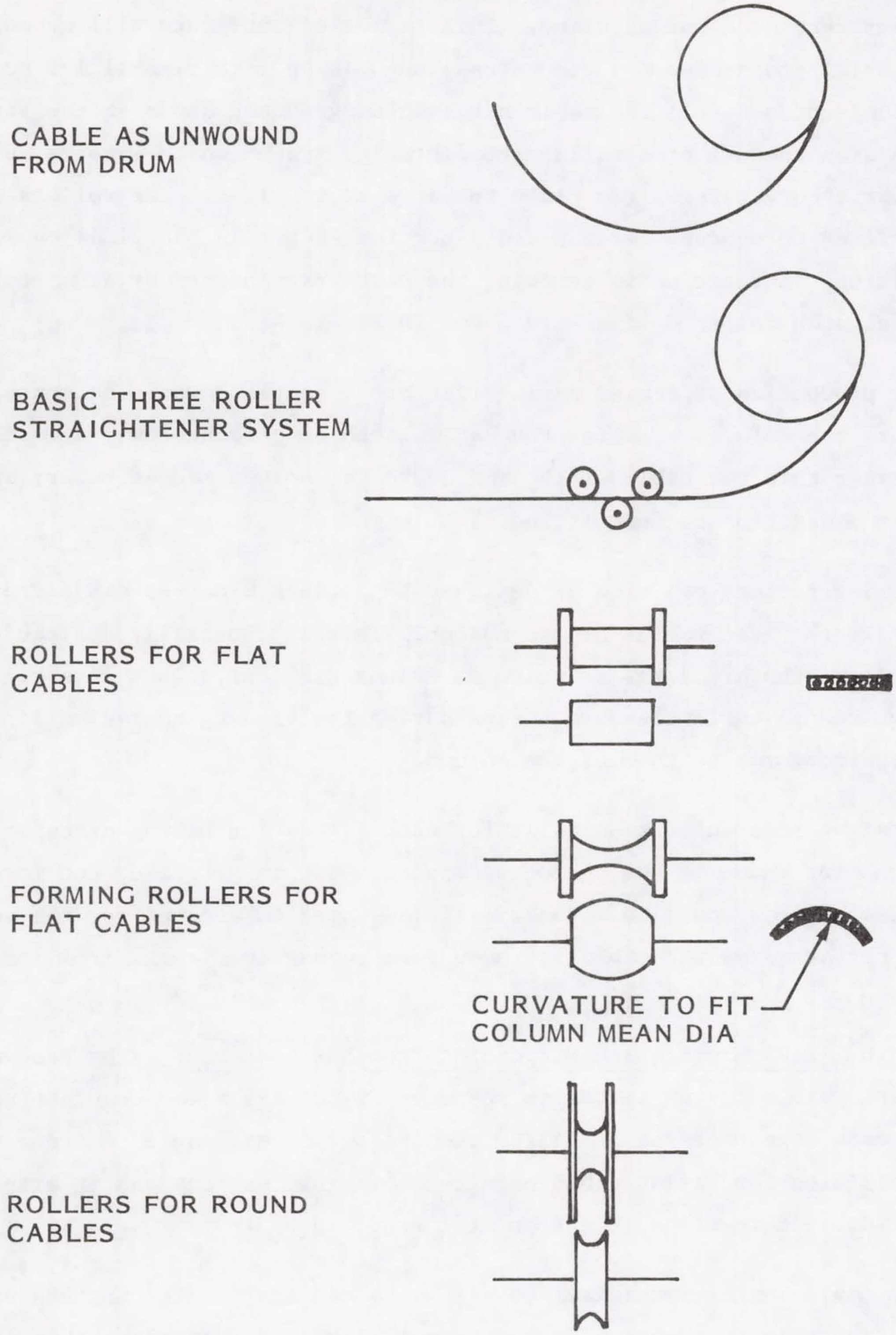


Figure 4-8 Cable Straightening Schematics of System

As shown in the top of Figure 4-8, the cable when unrolled from its storage drums retains a curved shape. This radius of curvature will depend on cable material properties and dimensions, but can be fairly small for common electrical conductors. The cable straightening scheme shown in the figure depends on the use of a roller straightening system which imposes sufficient reverse curvature on the cable to cause it to yield. The rollers can be designed to produce various cross-section shapes in the final cable configuration, in addition to removing the curvature induced by drum storage. Three such roller designs are shown in Figure 4-8.

The production of cables having flat cross sections would be appropriate where the columns to which the cable is to be attached have diameters much greater than the cable width, and where the column radius tapers appreciably from midsection to end fitting.

Forming rollers can also be designed to produce a curved cable cross section to fit the mean radius of the column. This is especially desirable when cable widths are large relative to column diameter, since less tension is required in cable tie-down straps during the binding operation if the cable shape conforms to that of the column.

Straightening rollers suitable for use with cables having circular cross sections are shown at the bottom of Figure 4-8. In practice, the force exerted by these rollers would be automatically adjusted to account for the varying degrees of curvature as the cable is removed in successive layers from its storage drum.

4.2.6 Reel Storage and Dispensing From The Assembler The general arangement of the cable laying system is shown on Figure 4-9. One complete unit is mounted at each corner of the gimballed parallelogram quadrangle in order to provide facilities for laying cable on either platform surface and in either platform surface and in either right or left hand traverses.

The cable laying mechanisms consist of a canister containing the cable wound continuously over one or several spools (about 80m of flat cable per spool) and a cable guide unit which performs three additional functions: pulling the cable from the spool, straightening it and binding it to the column. This complete system is mounted on 4 swinging arms which provide the necessary freedom to follow the columns surface while the assembler moves about. Figure 4-9 shows the assembler at mid-course during a right hand traverse between

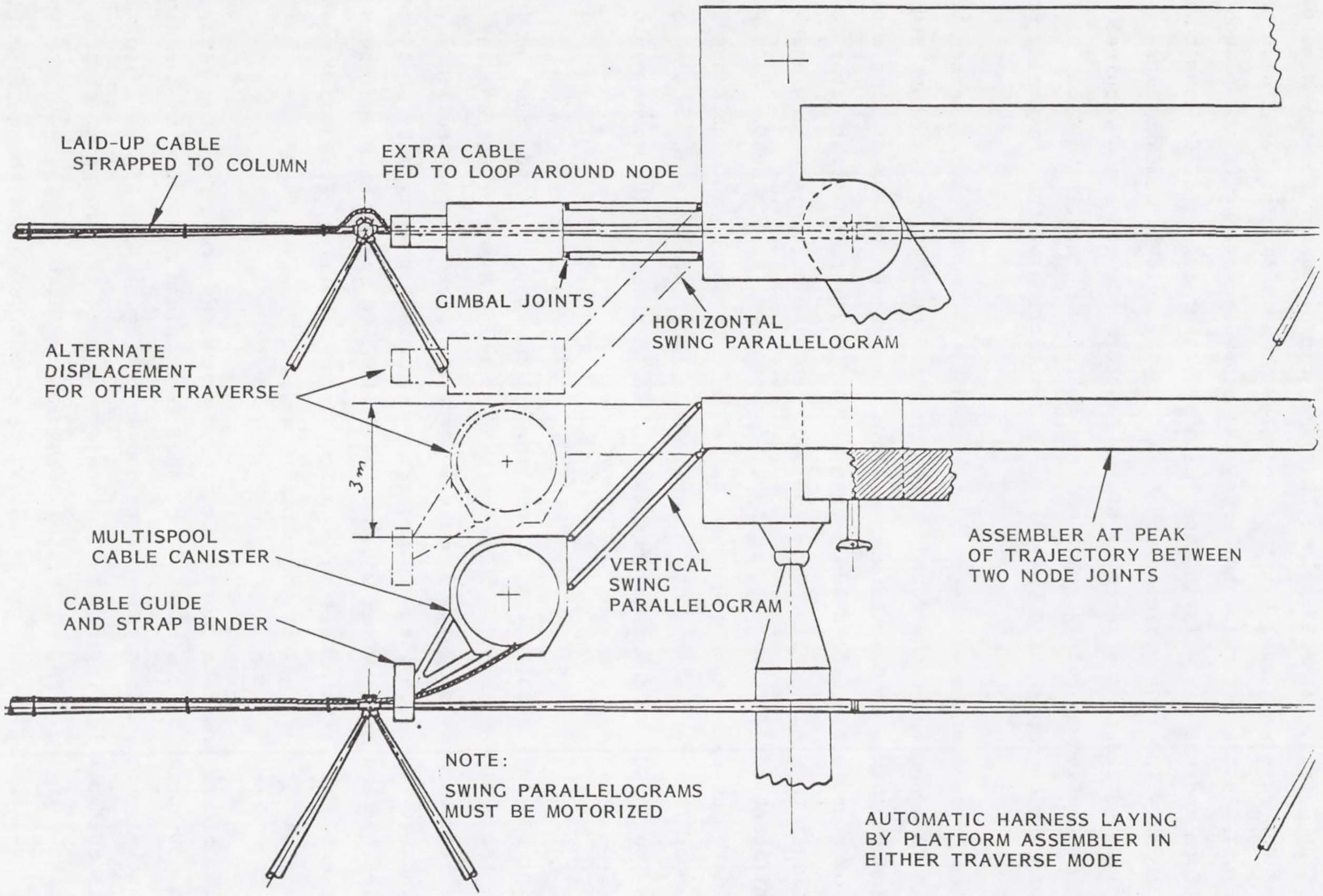


Figure 4-9 Platform Utilities Installation Electrical Harness

two node joints. At this point, the node joint retainer is approximately 3m above the retainer level but the cable laying unit remains level with the columns. In the alternate traverse, the assembler swings in the plane of the platform and the cable laying unit uses its other degree of freedom to follow its track. The true motion of the cable laying unit is somewhat more complicated due to the geometry of the platform structure and requires combined motion of both degrees of freedom for one repetitive cycle of each traverse (See report NASA CR-3131 for a description of the traversing motion).

In the present state of the conceptual study, it is not clear whether the flat cable is superior to the round cable for this application. A short study indicates that a 1m OD reel with a 200mm core can carry 80m of flat cable or 70m of round cable over a 100mm drum width. However, the flat cable is difficult to wind continuously and would require multiple reel winding with significant loss of space to restart from one reel to the next. A rough estimate indicates that the round cable could be stored in continuous length of about 700m per meter width of drum while the flat cable may not allow more than about 500m on the same drum width. On this basis, the round cable would appear preferable.

During the lay-up operation, the cable, either flat or round, must be drawn from the reel (or drum) in a controlled manner by a set of rollers and the reel must be provided with a brake in order to prevent uncontrolled unwinding. These devices are necessary because of the rigidity of these heavy cables (#4 and coax) which would normally tend to spring back and unwind to some extent. If this were to be allowed, the uncoiling cable would most likely jam itself against the canister wall.

Cable coiling presents another problem because, as drawn from the reel, it does not spring back straight but tends to retain a curvature on a radius about 1-1/2 to 2 times that of its stowed configuration. In order to make the cable suitable for laying it is necessary to draw it through a set of straightening rollers. A typical mechanism is shown on Fig. 4-10 for this purpose. Ideally, this device should be sensitive to the change in coiling

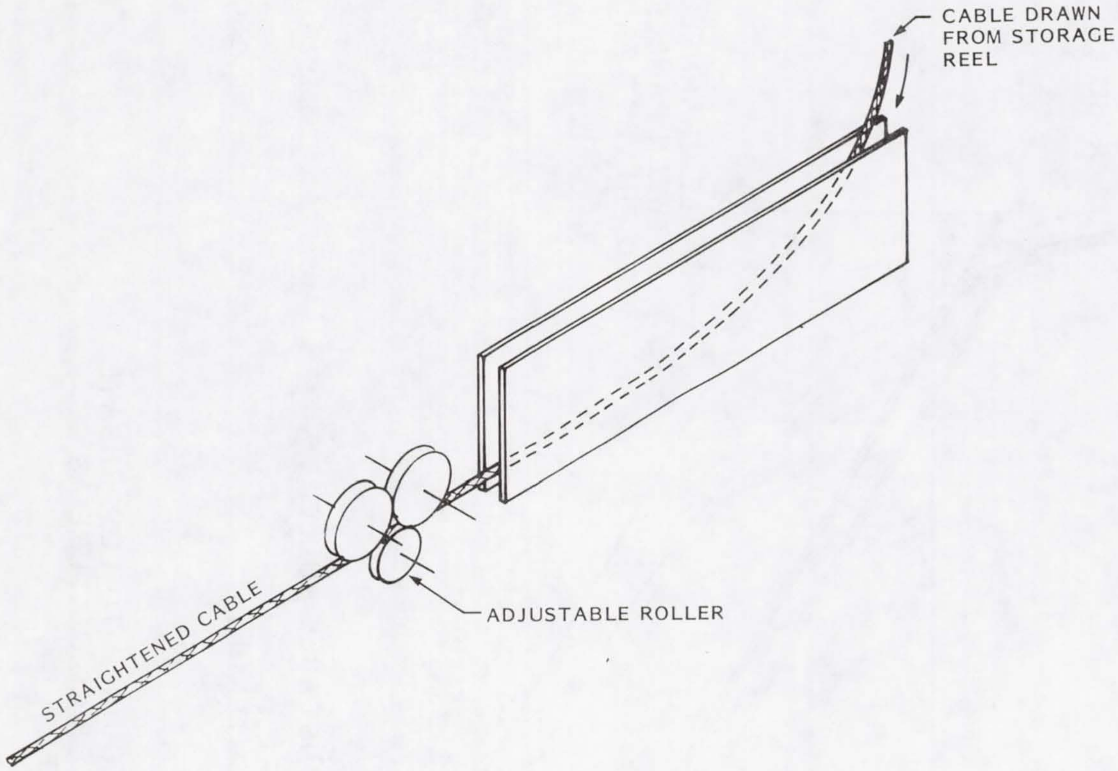


Figure 4-10 Cable Straightening Device

curvature as the cable is drawn from the drum and adjust the position of the center roller in order to output a continuously straight cable. It should also be oriented in such a manner that the output cable exits in a direction parallel to the axis of the column to which it is to be attached. In order to straighten round cables, it is necessary to draw it between sheaves having the appropriate shape and it is also necessary to ensure that the cable will not roll sideways as this would degrade the straightening. This last problem can be resolved by guiding a partial loop of cable between two walls as shown on Fig. 4-11.

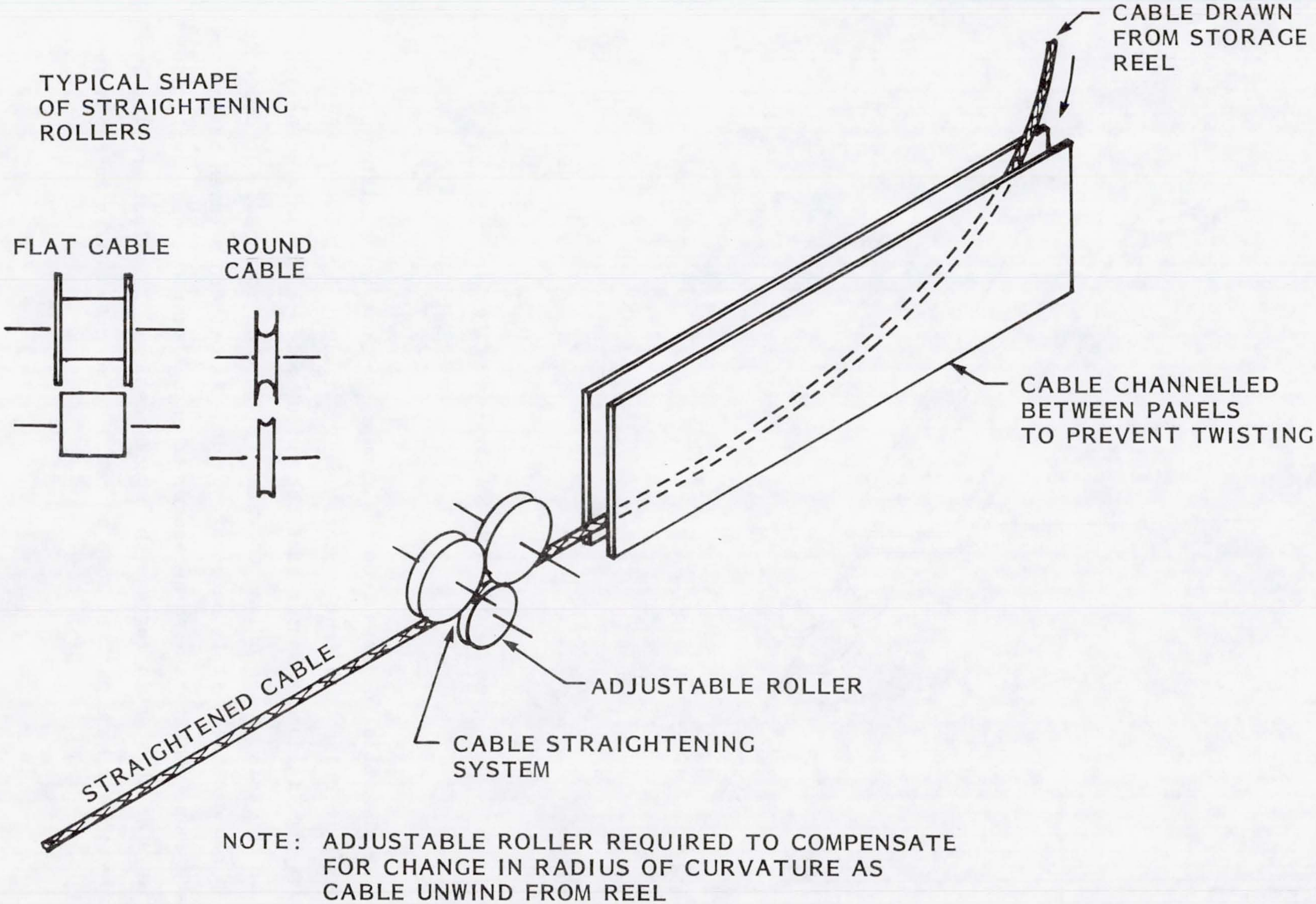


Figure 4-11 Prevention of Round Cable Twisting

Drawing of the cable around the node joints in such a manner that will not interfere with payload attachments can be achieved by joggling as shown on Fig. 4-12. A specified length of cable can be dispensed and laid up in the proper shape and position with, if necessary, the assistance of a specialized manipulator which could be a part of the whole cable lay-up system. It should be noted that lateral joggling of round cables is much easier than that of flat cables: this is another point in favor of round cables.

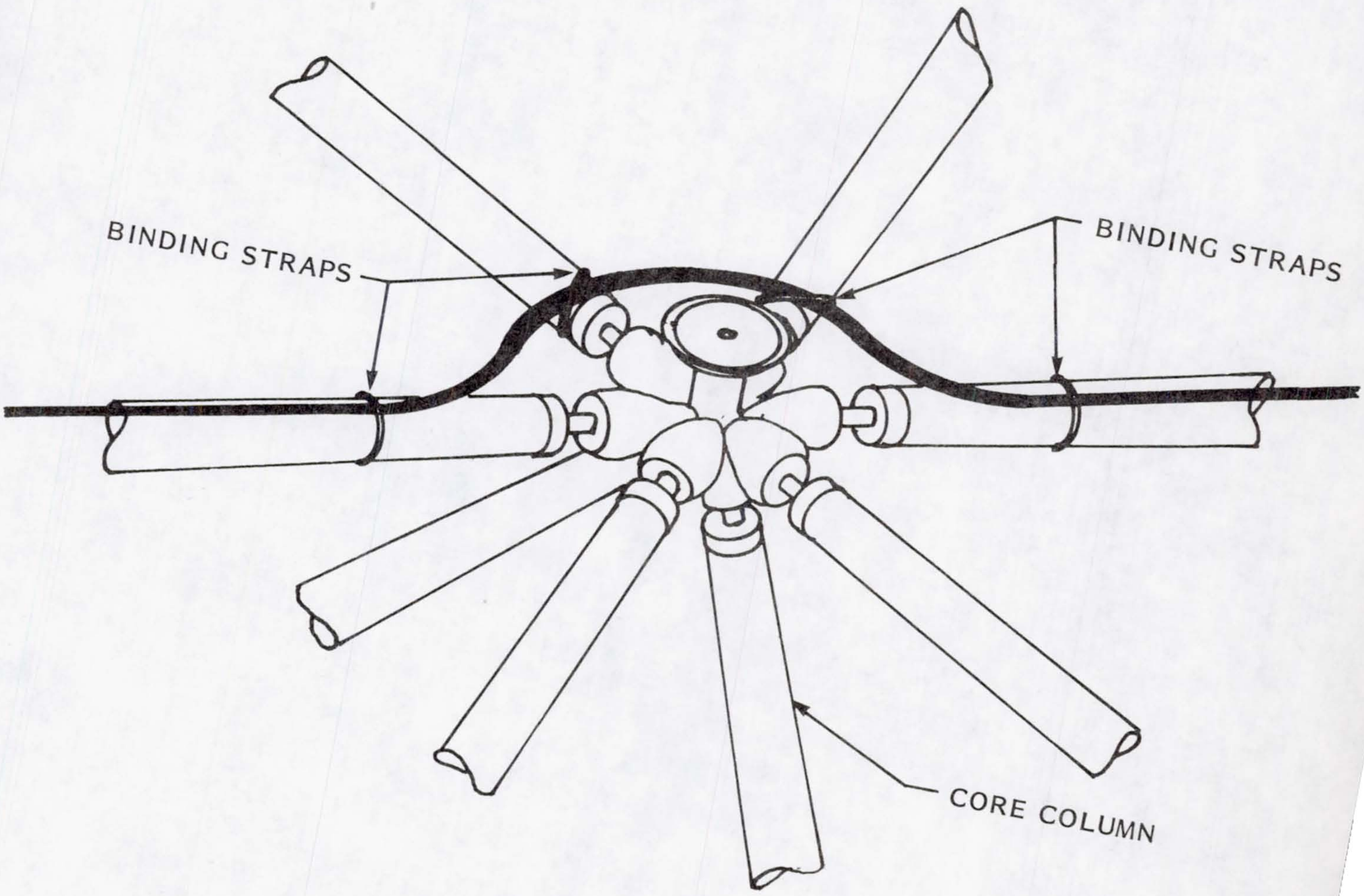


Figure 4-12 Cable Joggling Around Node Joint

4.2.7 <u>Segmented Storage in Column Canister and Dispensing from Column Assembler</u>

The cable laying concepts described above are mainly applicable to the upper and lower surfaces of the platform. Interconnection between these two surfaces require laying cables along the core columns.

For this purpose, it is necessary to consider a segmented configuration whereby portions of the harness can be assembled from one junction box to another using either standard or specially developed connectors. The concept under consideration consists in using cable segments with connectors at each end. These cable segments can be stowed straight in special canisters of the same length as the standard half-column canisters, to be extracted and attached to the column at the time of assembly. No particular problem is anticipated for columns of length less than or equal to the 17 m allowable in the Space Shuttle Cargo Bay. For longer columns (e.g: 20m) the canister length which cannot exceed 17m leaves 3m which must be bridged separately. In order to minimize the number of connectors, this bridging can be accomplished by having 1.5m long cables coming out of the junction boxes with manually operated connectors. Therefore, final connections will have to be performed by astronauts in the course of an EVA.

In this concept, the installation of cable segments would be accomplished concurrently with the assembly of the half-columns. Each cable segment would be individually stowed in a thin wall graphite epoxy tube from which it would be extracted by the half-column extractor system suitably modified to perform this additional function. An automatic binder, similar to that described for the traverse lay up system, will be used to attach the cable to the first half-column then, as the completed column is withdrawn from the canister, additional straps will automatically be placed at intervals on the other half-column. Thus, the equipped column can be transported by the carrier system to the manipulator pick-up points.

Although this egmented cable installation system can be mounted on anyone of the 8 arms of the platform assembler, its primary utility is expected to be on the two vertical members of the gimballed parallelogram. It should be noted also that under the present concept, the number of core columns carrying electrical cables is likely to be rather small so that the time expended during construction for installing these cables is probably not too significant.

A description of the half-column canisters and their column and cable advance mechanisms is given in the appendix.

4.2.8 <u>Segmented Storage in Separate Canisters and Dispensing by Separate Devices</u> In this concept we consider a self-contained cable canister as an add-on which does not disturb the standard half-column canister although it is operated through it. This approach would present some advantages for packaging in the Space Shuttle Cargo Bay. It would also permit transferring a partially empty cable canister from one assembler position to another thereby further saving packaging space. A schematic separate canister is shown on Fig. 4-13.

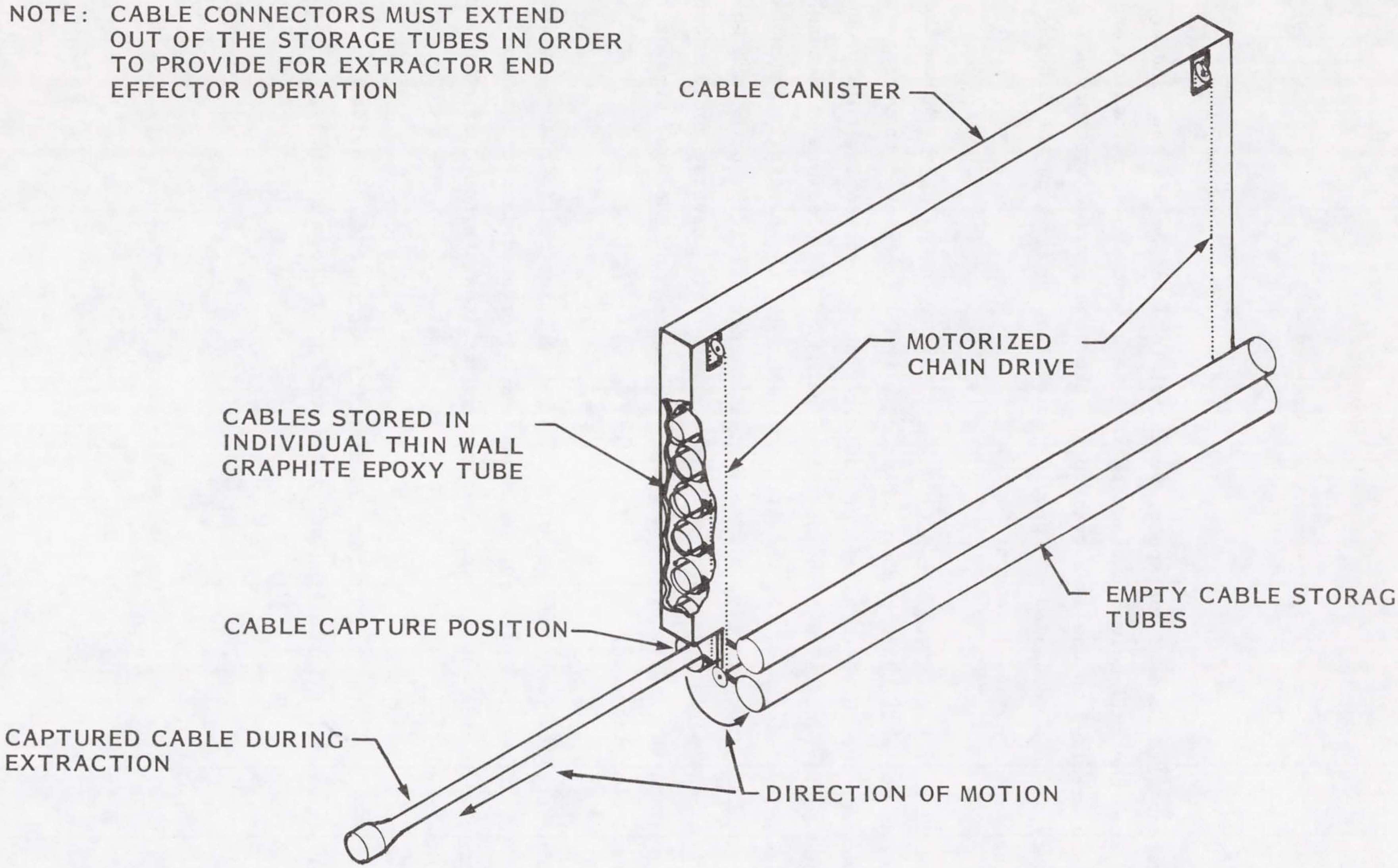


Figure 4-13 Separate Segmented Cable Canister

At the present time it does not appear practical to disassociate the binding mechanism from the half-column extractor since both functions (extraction and binding) are executed on the same track using the same carrier system. A future study of this mechanism may provide some clues from which the binding function can also be made a separate unit.

4.2.9 Sequence of Platform Construction With Utility Installation. Since the assembler has the ability to perform changes in the direction of traverses along anyone of the three sides of the basic tetrahedral triangle, this property can be used to lay utilities along specified paths of the platform structure. By a judicious selection of the construction sequence, the partially assembled platform can have, temporarily, a free edge along the utilities path such that the assembler can perform a cable laying traverse. This traverse could include a number of changes of direction and could be conducted at the same time as columns are being inserted.

Intersecting utility paths can be provided if a junction box is placed at the intersection. Then, the platform structure can be erected in sections and short segmented cables can be used whenever connections are too difficult for the machine to perform.

In general, advance planning of the construction sequence can provide a practical sequence for installing utilities during platform assembly.

4.3 PLUMBING ON THE PLATFORM

4.3.1 General Problem

The present requirements call for low pressure coolant circuits through pipes of about 1 inch diameter or equivalent cross-section. It is further postulated that fluid circuits will be relatively short (e.g.: between payload and nearby radiators) in order to minimize thermal problems which could occur with an extensive network of rigid tubing. In particular, thermal expansion of metallic tubing is troublesome in a graphite epoxy structure which is not sensitive to temperature variations. Special attention is given to this problem in the following discussion.

Five basic types of tubing are under consideration

1 - Thin wall tubing - aluminum, stainless steel, graphite epoxy
2 - Metallic flex hoses - stainless steel
3 - thin wall lenticular tubing - stainless steel, graphite epoxy
4 - inflatable - self-curing fiberglass tubing
5 - inflatable - fiberglass reinforced plastic tubing

They are shown schematically on Fig. 4-14.

Tubing No. 1 is of standard construction which needs no further description. This tubing must be selected with wall thickness sufficient to avoid damage in handling and during automatic installation. An alternative, the use of thin wall graphite epoxy tubing, would be a new technology.

Tubing No. 2 consists of a thin wall metallic bellow which provide degrees of freedom in bending and in tension-compression. However, extension is limited by an external braiding of metallic wires. Flex hoses are considerably heavier than the equivalent straight tubing hence, their uses must be limited to local applications to contour obstructions, absorb thermal expansion and provide flexibility to prevent misalignments of fluid couplings.

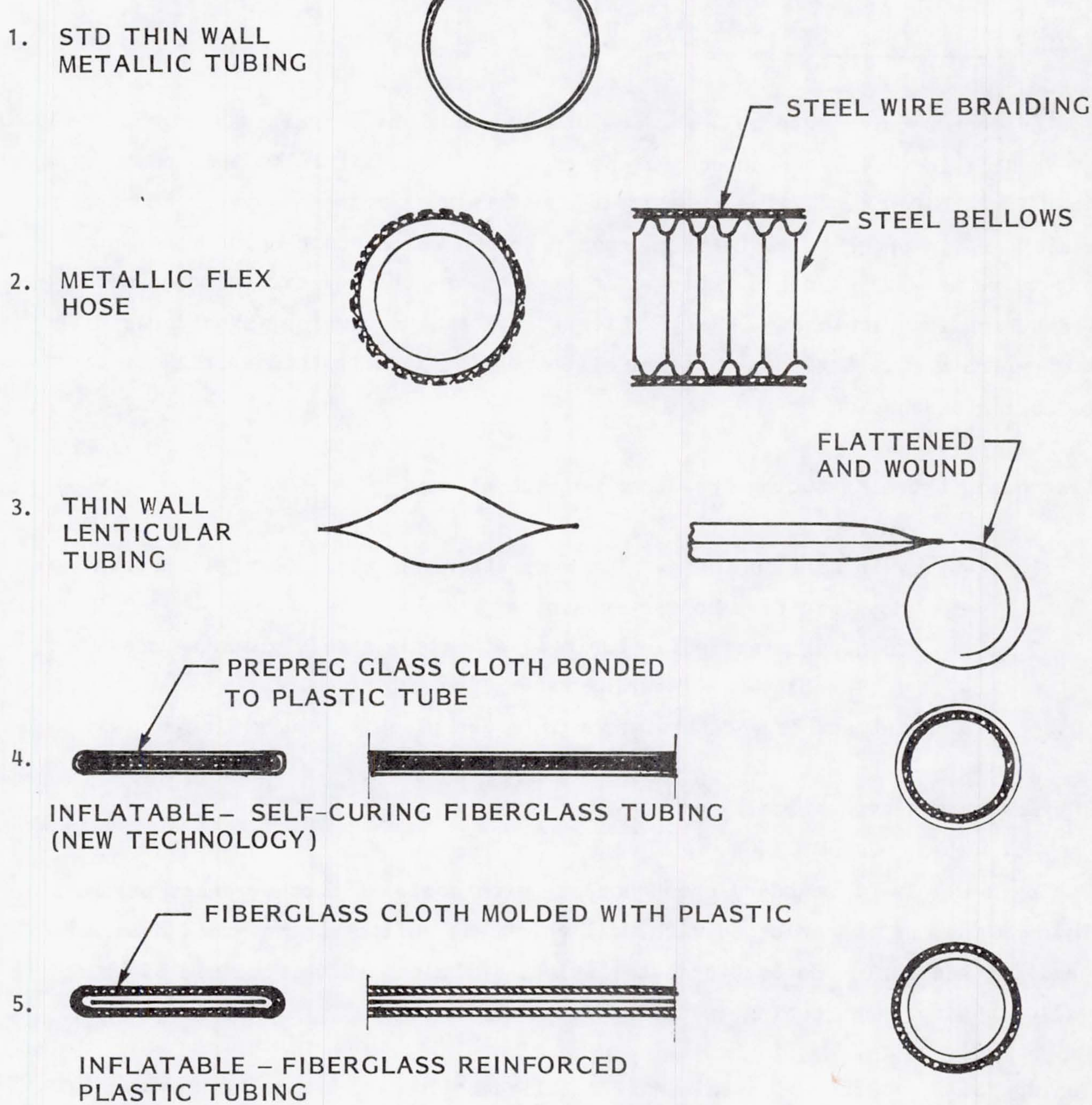


Figure 4-14 Five Basic Types of Tubing Cross Sections

Tubing No. 3 consists of two thin metallic plates bent to a sinusoidal cross shape and continuously welded together as shown on Fig. 4-17 to a lenticular shape. This tubing is not capable of carrying high pressures due to high stresses at the welds, but it can be flattened out and rolled around a drum in a tight package of great deployed length. However, considerable strain energy is built up in the tube by this winding and special devices must be provided to absorb it during deployment and retain control of the tube extension. Without suitable energy absorbing devices, this tube would unwind uncontrollably.

Tubing 4 is at the present time an untried idea. It consists of a fiberglass tube bonded inside an appropriate flexible plastic tubing. The fiberglass is impregnated with an epoxy resin and will remain soft and pliable until such time as a catalyst is brought in contact with it. In this condition, a considerable length of such a tube can be flattened and wound on a spool in a very tight package. Installation is simple and can be accomplished by mechanisms similar to the concepts described for electric cables. In some cases, tubing could be wound together with electric cables on the same reel. After the flattened tubing hose has been laid-up and all connections secured, it is inflated with a gaseous form of the catalyst and allowed to cure for the appropriate time. Finally, it is vented, flushed with compressed air and exposed to vacuum in order to dispel any remnants of catalyst. The tube network is then ready to receive fluid. The choice of the epoxy resin is important as it must be compatible with the expected service temperature range and with the fluid to be carried in the system. Special attention must be paid also to the binding of the tubing onto the structure. This binding must be adjusted loose enough to allow for inflation. This type of tubing is sealed by its plastic shell and can be adapted to use standard fluid couplings. It would be suitable for low pressure systems and would require development as a new product.

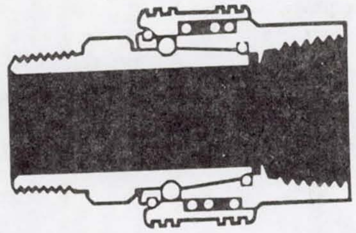
Tubing No. 5 is somewhat similar to a garden hose; it consists of a continuous plastic tube reinforced by a braided fiberglass casing bonded with a flexible agent. Such a tubing could be flattened, at least partially, to be wound over a drum or reel and dispensed in the same manner as tubing No. 4. Once pressurized, it would resume its normal shape which it would retain in service since there is no external pressure. This tubing should be satisfactory for low and moderate pressures.

4.3.2 Fluid Couplings and Junction Boxes

In the present concept, it is postulated that all piping is empty and unpressurized at the time of installation. This allows for the use of simple, light, standard fluid couplings. Two types of couplings must be considered: a straight-through model for interconnection in the network and a quick connnect-disconnect model (spillproof type) at the payload, pumps, radiators and other components. Typical couplings are shown on Fig. 4-15. This approach can be taken in order to save weight and cost because a fluid leak along a line is likely to be detected only by its effect on the supply of coolant. Hence, the pipes would be vented out before repairs can be performed. The fluid network should include a number of automatic isolation valves sensitive to a parameter such as pressure drop to prevent large losses of coolant.

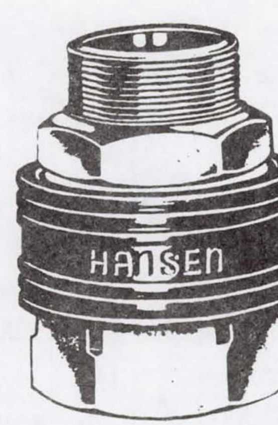
The fluid couplings should be of a standard push-pull self-locking type which can be easily handled manually by astronauts in EVA. It does not appear practical, at the present time, to perform the connection by means of automatic devices because of the complexity of the mechanisms which would require target seekers, remote manipulators and special end effectors.

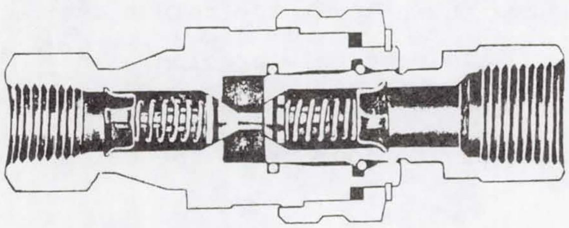
Junction boxes will be required for brach connections and to install isolation valves and other components of the fluid system. Ideally, these junction boxes should be combined with the electric junction boxes since in most instances, power and fluid lines will run concurrently.



STRAIGHT THROUGH BORE

SERIES ST





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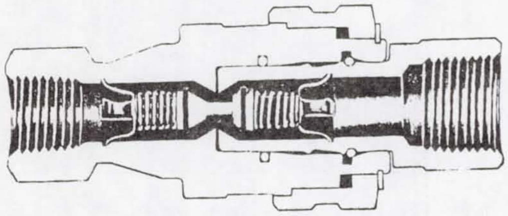

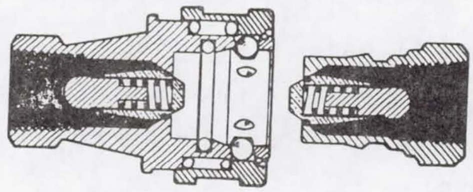

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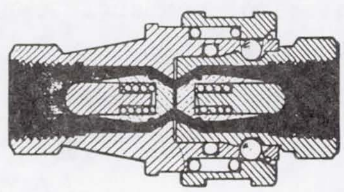

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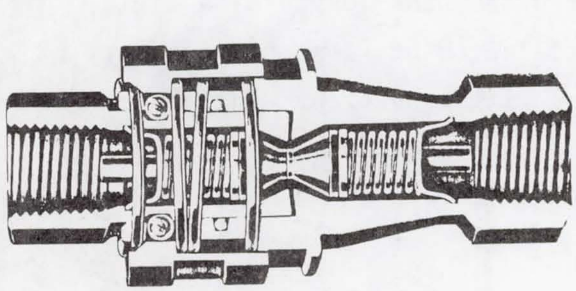

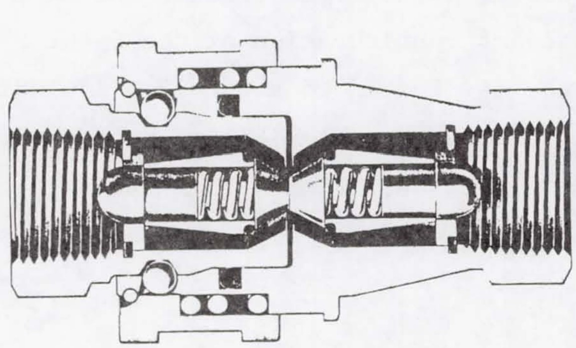

Fig. 4-15 Typical Fluid Couplings

4.3.3 Piping Installation

4.3.3.1 Geometric Constraints

The characteristics of the space platform structure impose some constraints in laying piping, especially in the case of rigid tubing. The double conicity of the columns does not permit safe binding of a straight tubing alongside. It is, therefore, necessary to provide a kink in the tubing over the column center fittings. Flexhoses will conform easily to eliminate this problem. In the case of straight tubing of type 1, the addition, at midspan, of a short piece of flexhose gives it the necessary flexibility to conform to the column shape.

The problems of geometric constraints do not exist in the case of the inflatable fiberglass hose.

In the case of short columns (5 m to 10 m) it is possible to leave the rigid tubing, round or lenticular, unsupported to span from node joint to node joint. Then, the fluid lines could be installed parallel to the columns and at some short distance from the node joints. The installation of tie-straps over an intersection of two elements can be accomplished by appropriate modification to existing automatic tie wrappers. This technique is applicable to any rigid tubing, round or lenticular and made of metal or composite material. In the present configuration of the Space Shuttle Cargo Bay, the length of a rigid tube is limited to about 17 m including a short length of flexhose necessary to provide the flexibility needed for fluid coupling insertions and for changes in direction. Fig. 4-16 gives a general idea of this concept.

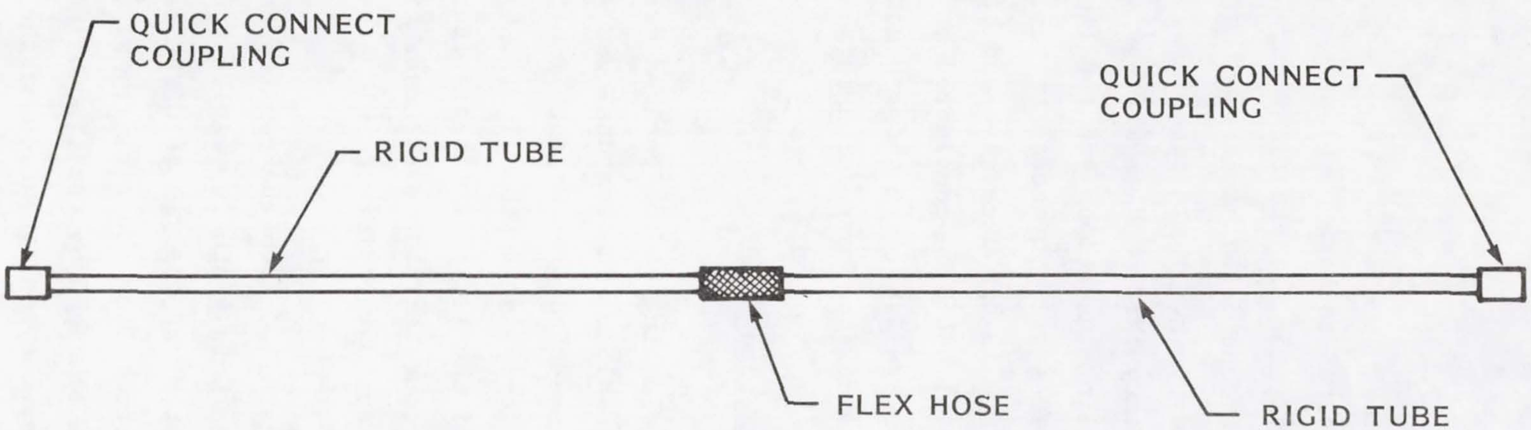

Fig. 4-16 Schematics of Rigid Segmented Tube

4.3.3.2 Thermal Constraints

The platform structure is expected to be a combination of graphite epoxy plus small aluminum fittings and has, for all practical purposes, a coefficient of thermal expansion which can be considered as zero. Therefore, whenever dissimilar materials will be used, (e.g., rigid plumbing), thermal stresses will be generated. To a great extent, this problem will be alleviated by the flexhose components necessary for coupling insertions and for line changes in direction, but in some cases special devices will be needed to relieve thermally-induced stresses. If the fluid pressure is not excessive and below the save capabilities of graphite epoxy, this material could be considered as a strong contender for the tube material. Techniques are available to manufacture graphite epoxy tubing with braided fibers having good hoop strength.

4.3.4 Plumbing Installation Methods

The method of installing the plumbing can be derived directly from the concepts established for the electric cables. These techniques were thought of with cables and piping in mind in order to provide for simultaneous installation of both networks. Thus, the cable laying system of Fig. 4-2 can be adapted to install either cable or one of the flexible pipes: lenticular or inflatable. A problem of crowding could occur near the small ends of the columns. It will require special attention to avoid interference with the node joints.

Rigid tubes can be readily installed from the canister stowage system described on Figs. 4-3 and 4-13, by alternately stowing cables and tubing and adapting the extractor and binding systems appropriately. The major differences from the power cable installation stem from the rigidity of the tubes. The details of these operations will be influenced by the type of mechanism selected to perform these functions and by the configuration of the electric cables and

tubing segments. It should be kept in mind that this utilities installation procedure is designed for application to the core columns (i.e.: on the two vertical members of the assembler) and occasionally to cross members (i.e. on the swing arms of the assembler). Cross members are defined here as those columns of the upper or lower face of the platform which are not along the path of a traverse as shown on Fig. 4-2.

Section 5

COMPARISON OF THE VARIOUS CONCEPTS

The best method of approach to the solution of the utilities installation problem will necessarily depend on the physical characteristics of the selected cables and tubings. The main parameter which must be considered is the rigidity of the electric cables and fluid carrying pipes, i.e.: whether they can be rolled in drums or reels or must be presented as straight elements of fixed length with multiple interconnections. Another parameter of importance is the number of interconnections which can be permitted to retain an acceptable level of reliability.

It should be noted that electric cables and fluid carrying pipes can be selected to have similar mechanical characteristics so that the laying process designed for one is equally applicable to the other. This feature is of significant importance since a single system having capabilities for both applications would prevent much duplication, reduce complexity, save weight and in some cases allow simultaneous installation of electric cables and fluid lines.

In selecting an appropriate method of laying either electric or fluid networks, one should not loose sight of the constraints imposed by the platform structure and by the operating characteristics of the Gimballed Parallelogram Assembly machine. It has been shown, in the discussion of Section 4 that the equipment of the platform structure presents two different problems:

1 - laying utilities on the upper or lower face of the platform.
2 - laying utilities along the core columns.

It has been shown also that continuous laying from one face of the platform to the other face appears, from a general standpoint, to be beyond the realm of practicality. It is, therefore, necessary to consider a multiple approach to solve separately the installation of utilities along columns forming the upper and lower faces of the platform and those which form the core of the platform.

Connections of the various components of the electrical harness and of the fluid line network has been considered as a manual operation to be performed by astronauts in EVA. The installation of junction boxes is also considered as a manual operation. In all cases, snap-on, self-locking couplings should be used so that installation of junction boxes on node joints, connections of the electrical harness and fluid line couplings can be performed without special tooling.

Since all coupling operations must be performed in vacuum with pipes open at both ends, straight through bore couplings (Hansen series ST - typical) may be used. However, the standard industrial couplings should be modified to include a straight snap-on locking capability without requiring the operation of alock ring.

5.1 Selection of Effective Installation Techniques

An examination of the various concepts presented in this report indicates that candidate installation concepts shown are potentially applicable to different tasks as follows:

5.1.1 Top and Bottom Faces of Platform

a) Round electric cables which can be efficiently wound over reel or drum
b) Collapsible fluid lines which can be efficiently wound over reel or drums
c) Reel (or drum) type distributor as shown on Fig. 4-2 and 4-9
d) For installation during construction of the platform, preference is given to the scheme of Fig. 402: distributor attached to the assembly machine. This scheme requires precise planning of the assembler sequence of operation in order to lay the cable (or pipe or both) along the prescribed path.

5.1.2 Core Columns

a) The scheme of Fig. 4-3 is applicable with either rigid or flexible cables and fluid lines. Half-columns, cables and fluid lines are drawn simultaneously from canisters and attached together mechanically. The platform assembly machine then transports this sub-assembly and inserts it into the framework where the utilities are ready for manual connection.

It should be noted that the scheme of Fig. 4-3 is applicable to any member of the platform assembly machine. In this case, it may be used to set up branching from a main line or for other functions requiring special consideration. If its use is only intermittent, the scheme of Fig. 4-4 may be more convenient since a separate utilities canister can be moved (by EVA) to another location to dispense remaining supplies of cables or pipes.

5.2 Feasibility Assessment

The schemes selected in Section 5.1 are believed to be conservative and make use of current technology which can be easily adapted to perform the taks required. Although complex, the automatic control system required for the operation of these schemes remains well within the State of the Art. All operations must be performed sequentially and a number of them must be coupled with the displacement of the platform assembly machine.

5.4 Impact Analysis

The effect on construction time of installing utilities during platform assembly cannot be assessed precisely in this study because, at this stage, a baseline platform has not yet been defined. However, a qualitative assessment of the impact of the utilities can be given as follows:

- A reduction of the number of columns which can be carried by the Space Shuttle as a consequence of the volume needed in the cargo bay to carry electric cables and piping canisters. Therefore, a smaller platform will be erected for each flight.

- Erection time will be adversely affected because the assembly will proceed more slowly whenever utilities are being laid. As a first estimate, the time required to install a column, concurrently with utilities, can be taken at twice the original value of Ref. 1.1.

- The complexity of the required utilities network will have an important influence on the erection time. If the network is simple, then the erection time may not be greatly affected since only a small number of columns will require utilities installation. However, a more complex network may significantly reduce the efficiency of the platform assembly. To some extent, this detrimental effect can be alleviated by careful planning of the network and time studies of the assembly operation.

- The presence of additional hardware required for utilities installation will certainly complicate the problems of packaging the platform assembly machine into the Space Shuttle Cargo Bay. Since the utilities installation equipment is of a fixed size and practically independent of column length (i.e.: independent of platform assembly machine size), it will require a fixed volume in the Space Shuttle Cargo Bay. This reduction in cargo capacity will be felt on the number of column canisters which can be stowed in the cargo bay together with the smaller assemblers; but, in the case of the larger assemblers, it may lead to a two-flight requirement to place the complete machine on orbit.

- The presence of utilities has an impact on canister packaging in the Space Shuttle Cargo Bay. Either larger or additional separate canisters must be part of the payload. This will have an adverse effect on the number of columns which can be taken for each flight, especially in cases of large complex utilities networks. The platform size which can be built for each flight will be reduced and the overall time required to build a given size platform will be increased.

- The number of Space Shuttle flights required to lift the supplies of columns, node joints and utilities is not significantly sensitive to the method of utilities installation. If the utilities were to be installed in a separate operation, special flights would be required to lift the hardware. Therefore, it is most likely that combining platform assembly and utilities installation will be a more efficient then two separate operations.

- In the normal platform assembly as described in Ref. 1-1, the role of the astronaut in EVA is purely supervisory. Except for loading and unloading canisters on the machines, manual work is limited to inspections and assistance to the machine in cases of malfunctions.

Utilities installation requires manual work as an integral part of the assembly. This work consists in installing junction boxes and connecting both electric and fluid network components. Appropriate design of clamps and couplings will make it possible to perform this work without using any special tooling.

- o The proposed method of utilities installation does not depend on special features of the platform structure. Therefore, the design of Ref 1-1 is directly applicable. It is also independent of the method of column couplings so that any type of node joints may be used.

- o The proposed method of utilities installation has only minimal impact on the Platform Assembly Machine. Reel wound utilities require attachment points to the basic machine structure and computer software for their control. Segmented utilities distribution does not affect the basic machine structure as they are designed as parts of the half-column assembly system. They will also require computer software for their control.

- o The operation of the Platform Assembly Machine is modified during utilities installation. Two cases must be considered.

    a) Laying of reel-wound utilities during a traverse: The motion from one node joint to another must be broken into a number of steps to allow for binding of the utilities to the column at specified location. In general, it can be considered that 6 ties will be required on a 20m column down to 4 ties on a 5m column. Hence, the number of steps may vary from 4 to 6.

    b) Laying of segmented utilities. In this case, it is the operation of the half-column assembly which is involved. It does not affect the general machine operation except for

allowing more time for column insertion at each step of the traverse where segmented utilities are being laid.

5.5 Automatic Insertion of Electrical Connectors and Fluid Couplings

In order to provide for a fully automatic utilities installation, that is, an installation procedure completely independent of astronaut EVA activities, it is necessary to mechanize the insertion of electrical connectors and fluid couplings. To perform this function automatically, the mechanism needs to go through a rather complex sequence of events such as:

1. Recognize the objects which must be connected together
2. Capture the two components of the coupling in a manner suitable for connection
3. Orient the two components to face each other
4. Rotate the two components for indexing appropriate markings so that they will be aligned in the proper positions
5. Advance the two components toward each other until mated
6. Safety lock the coupling

It is assumed that the above mechanism will be positioned in the near vicinity of the coupling to be connected by a programmed control system as yet unspecified. Then special sensors will perform the following sequence:

a. Look for the two half-couplings
b. Determine their exact position and orientation (which may be random)
c. Position the capture mechanism accordingly
d. Activate the capture mechanism to seize the two half-coupling at the specified strong point.
e. Select the appropriate sequence of maneuvers to present the two half-couplings in front of each other

When installing utilities concurrently with platform assembly, a number of items should be considered:

At a particular connection, some components of the network may be installed in the next traverse step. Connection at that point requires a backward step of the assembler i.e: a time consuming procedure.

It can be assumed, "a priori", that electric connectors and fluid couplings will be compatible from the coupling standpoint. If this is not the case, separate mechanisms must be designed to meet different requirements although they may be operated by the same control system.

In the present state of this conceptual study, it does not appear practical to attempt further definition of an automatic coupling insertion system the complexity of which seems to be excessive by comparison with the task required. Therefore, EVA is considered essential to perform these connections, install junction boxes and other small auxiliary equipments while at the same time performing the necessary visual inspections of the networks.

The problems of the automatic coupling connection should be reviewed in a more advanced study of the utility network installation once the complete operation is more precisely defined. In the meantime, EVA is considered as a practical solution from an experimental standpoint and for smaller platforms carrying moderate networks.

Section 6
CONCLUSIONS

The results of this study show that, to a large extent, the difficulties of installing utilities on large space platforms depend on the type of electric cables and fluid pipes available. Rigid elements present problems which are difficult to resolve simply. Appropriate solutions are generally more complex and more expensive. Electric cables can be easily wound over drums or reels and it is desirable to have fluid conduits with the same properties in order to use the same dispensing mechanism for both.

In the present state of the art, it does not appear practical to design a fully automatic system which would attach the utilities to the Space Frame and perform all connections without human assistance. Therefore, at the present time, EVA is considered essential to install junction box and connect both electric and fluid lines.

The possibilities of using built-in wiring in the column were examined with the conclusion that only low power signals could be transmitted in this manner because of geometric limitations at the small ends of the columns and because of possible detrimental thermal effects of hot wires on the epoxy. Furthermore, severe problems of interconnections cannot be resolved satisfactorily at the end as well as the center of the columns. This technique is considered impractical for thin wall (.8mm (.025") thick) which must be stacked "plastic cup" fashion.

Fiber Optics were also considered as an alternate to built-in wiring as they do not have the potentially detrimental thermal effect. However, problems of connections across joints are more difficult to solve than with electric systems and would lead to weakening or possible loss of the signal.

The proposed solution consists in using continuous laying of utilities (electric and fluid lines) between junction boxes on the faces of the platform and segmented utilities along the core column. This technique can be applied with state of the art material, relatively simple modification to the basic Platform Assembly Machine and a minimum of losses in construction speed and flexibility.

SECTION 7
RECOMMENDATIONS

There is clearly a great advantage in using flexible tubing for the fluid lines because of the commonality which can be achieved between electric and piping laying machinery. Therefore, the first recommendation concerns the development of such tubing along the lines of either the self-curing or the simple reinforced types of the inflatable glass reinforced tubes shown on Fig. 4-14. Development of this tubing should include design, fabrication, pressure testing, tolerance to long time stowage and method of attachment to the columns prior to inflation.

The most effective method of attaching utilities to the columns appears to be by means of wrap-around self-locking ties similar to those normally used for wire bundles. Fully automatic installation tools are available with capacities up to 33 mm (1.30") diameter. In order to meet the requirements of this study such devices must be scaled up to place ties over a range of diameters from about 60 mm to 250 mm with the capability of retrieving all debris. Such a development program would be best performed in collaboration with a specialist.

The technique recommended to install utilities on a Space Platform consists in making maximum use of the Platform Assembly Machine capabilities in laying cables and piping, leaving only simple operations for EVA astronauts to perform. In this context, the design of the electric connectors and fluid couplings is of great importance as they must be capable of smooth and effortless insertion and automatic lock-up without requiring specialized tools beyond the normal astronaut kit. Ideally, this connection should be performed with free hands. Additionally, connectors and couplings must be small enough to be wound on the drums and reels together with cables and hoses. Development of adequate connectors and couplings is needed based on existing

standard model technology. It should be noted that the space suit provides considerable restraint on wrist twist, therefore, the connection mechanisms should avoid the use of ring nuts and other threaded or bayonet mount systems.

APPENDIX A

Laying Flat Cable from Multireel Stowage

Figures A1 and A2 illustrate one design concept for laying of flat cable along the columns. Figure A1 shows placement of the multireel apparatus in the overall column assembler; Figure A2 shows some details of the multireel apparatus. In Fig. A1, the flat cable is wound on a multi-flanged spool or reel of about 1 m O.D. by 0.3 m I.D. The reel illustrated has an overall length of approximately 0.8 m, which is sufficient to accommodate seven tiers of the 100 mm wide flat cable. At 80 m of cable per tier, a total of 560 m of cable would be available before the multiflange reel was empty.

In operation, the multiflange reel is loaded into a hopper or magazine and supported on hopper-mounted rollers which permit both rotational and translational motion of the reel assembly. A latch on the end of a ball screw is used to engage a catch in the reel. The reel can then be moved in translation by rotation of the ball screw. A reversible stepper or sequence-controlled motor pulls the spool to the right by means of the ball screw until the right-most (end) flange of the spool is in position to begin the cable laying sequence. The spool is rotated by means of a gear and drive motor assembly, the drive gear mating with teeth on the reel's flanges.

To start laying cable, the cable end connector is first threaded through a slot in the hopper and through a series of rollers mounted below the hopper. A swing link rotates the bottom rollers far enough outward to provide clearance for the end connector as it is threaded through the series of rollers. It is assumed that the threading process, which must be done to clear the connectors on each end of each 80-m cable length, will be an EVA task.

After the end of the 80-m cable has been threaded through the rollers and cable trying mechanism, the lower roller link is latched back in closed position, the drive motor for rotation of the cable reel is energized, and

cable is payed out as the reel rotates and as the assembler moves axially relative to the columns. As the apparatus moves and lays cable along the column, the cable is attached to the column at intervals by means of a tie mechanism similar to those currently used for automatic cable tying operations (see, e.g., Fig. 4-10 in the body of this report). Variations in column diameter during the cable laying operation can be accommodated either by a tensioning roller on a spring-loaded traveling center or by appropriately moving the entire cable reel hopper on its parallelogram linkages. Also as cable laying proceeds, the entire cable reel hopper is raised and/or swung sideways by the parallelogram linkages to clear the column node joints at 20 m intervals.

After one tier (approximately 80 m) of cable has been layed, reel rotation is stopped, the reel rotation drive disengaged, the lower roller link released and lowered, and the end of the cable with an attached end connector threaded through the roller and tie mechanisms. The ball screw is then used to advance the reel one more tier to the right, until the next succeeding tier engages with the reel rotation drive gear. The new tier cable with end connector for the new tier cable is then threaded through the roller and tie mechanisms, connected to the cable layed up from the previous tier, and the cable laying operation started again. This process is repeated until the cable from all tiers has been layed. The operation is then stopped, the hopper opened, and EVA used to remove the empty reel and replace it with a full new multiflange reel of cable.

Figure A2 illustrates a 7-tier reel; however, more or fewer cable tiers could be used. The actual number of tiers per multi-flange reel will probably be determined by EVA limitations and/or by space shuttle reel stowage geometry.

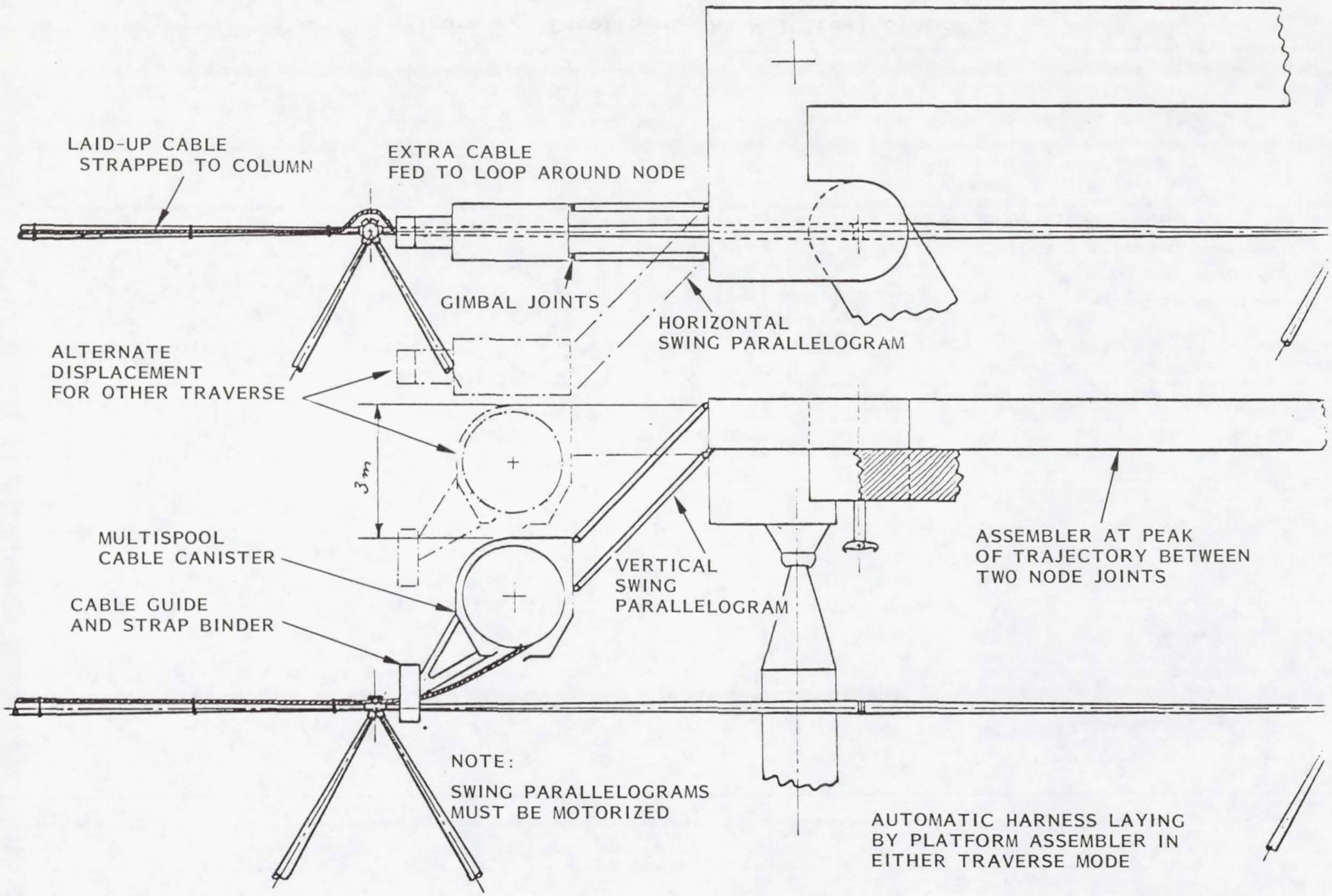

Figure A1 Platform Utilities Installation Electrical Harness

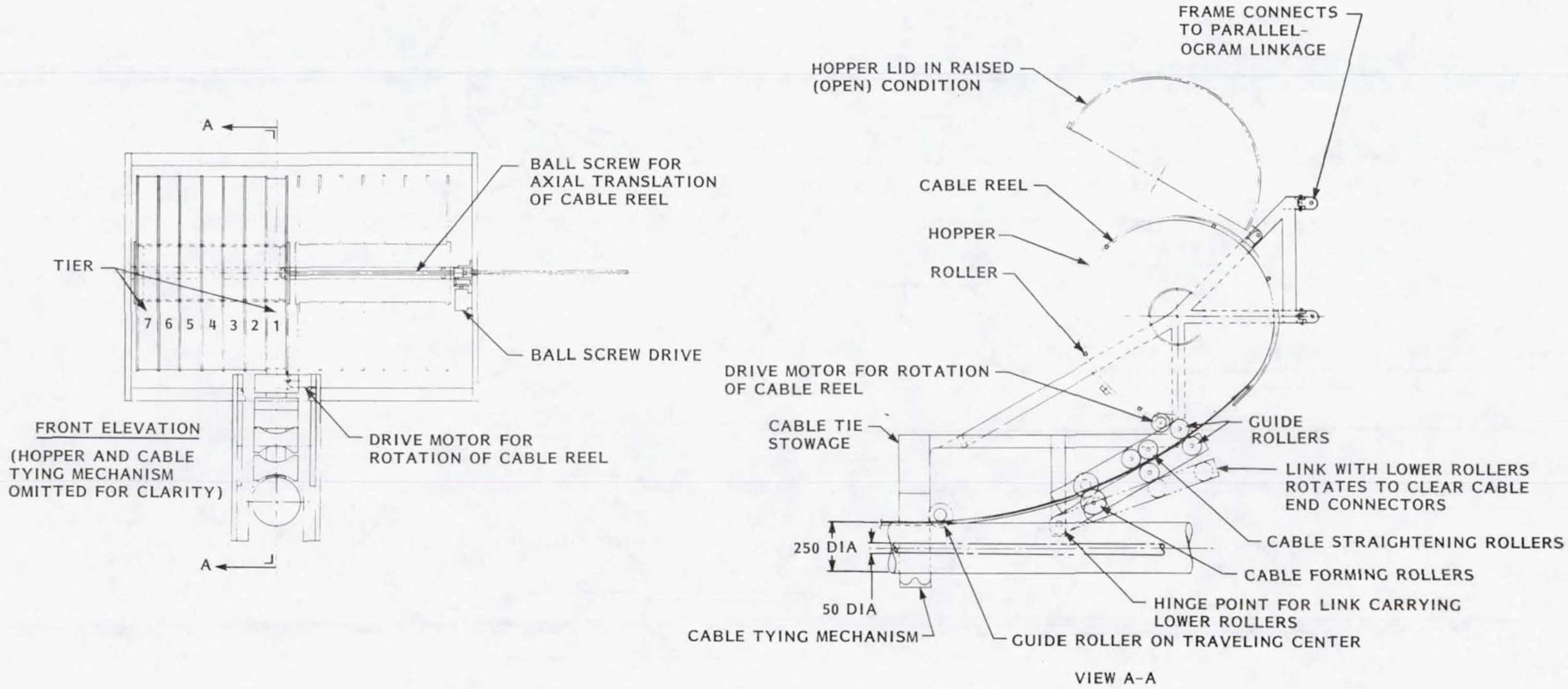

Figure A2 Details of the Multireel System

APPENDIX B

Canister Storage and Extraction of Electrical Cables

The 17-m long cables consist of a bundled group of individual cables equivalent in size to nine No. 4 AWG and four No. 12 AWG conductors. The end connectors required for this number of conductors will correspond to a standard No. 40 connector shell size, which has an outside diameter of 70 mm (2.75 in). The cable bundle itself will have a diameter of approximately 38 mm (1.5 in).

One concept for storage and deployment of the 17 m cable segments with end connectors is shown in Fig. B1. The basic half-column canister is 584 mm by 1420 mm in cross section and 17 m long. To this basic canister is added an additional 74 mm in width to accommodate a stack of 18 cable segments. Each of the cable segments is contained in a thin-walled, graphite epoxy tube. A stepper motor, sprocket, and chain drive system is used to advance the individual tubes to the bottom of the canister, where a mechanism added to the half-column extractor system extracts the 17-m cable segment from the tube.

The individual tubes are carried or supported on special attachments to the 9.5 mm (.375 in) pitch chain drive, as shown in Fig. B-2. These special attachments are similar to standard fittings currently used on various chain and conveyor system drives. The graphite epoxy tubes are secured to the special attachments by means of aluminum collar clamps, one near each end of the tube. Additional ascent load support could be provided by lugs (not shown) attached to the front end of the canister. Removal of the canister cover would free the front end of the tube/cable segment from the FWD. support lugs and expose the cable segment end connector for pickup by the extractor system.

A detailed sketch of a conceptual front-end electrical connector for the 17-m cable segment is shown in Fig. B-3. One side of the connector has a square flange which furnishes space for two hook engagement slots. Suitable programmed auxiliary arms/hooks on the extractor system would be used to engage

these slots and withdraw the cable segment to a position where it could be grasped by a working head mechanism like the one used to manipulate and mate the half-column sections.* The square half-flange on the end connector could also be used for guiding and indexing the cable segment as it is handled in the working head mechanisms; in addition, a circular groove is provided near the front of the connector to facilitate handling by the working head mechanism.

*This working head mechanism is described on Fig. 31 and 32 of NASA CR-3131.

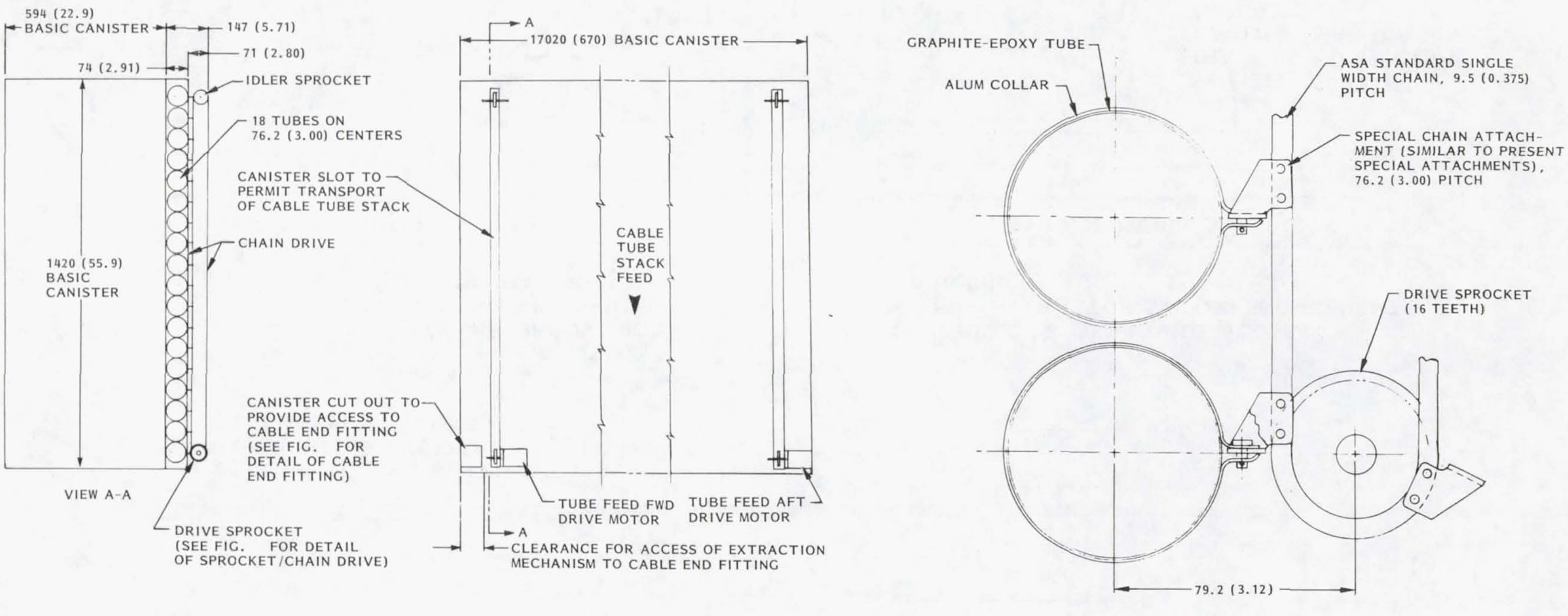

Figure B1 Electrical Cable Stowage in Canister

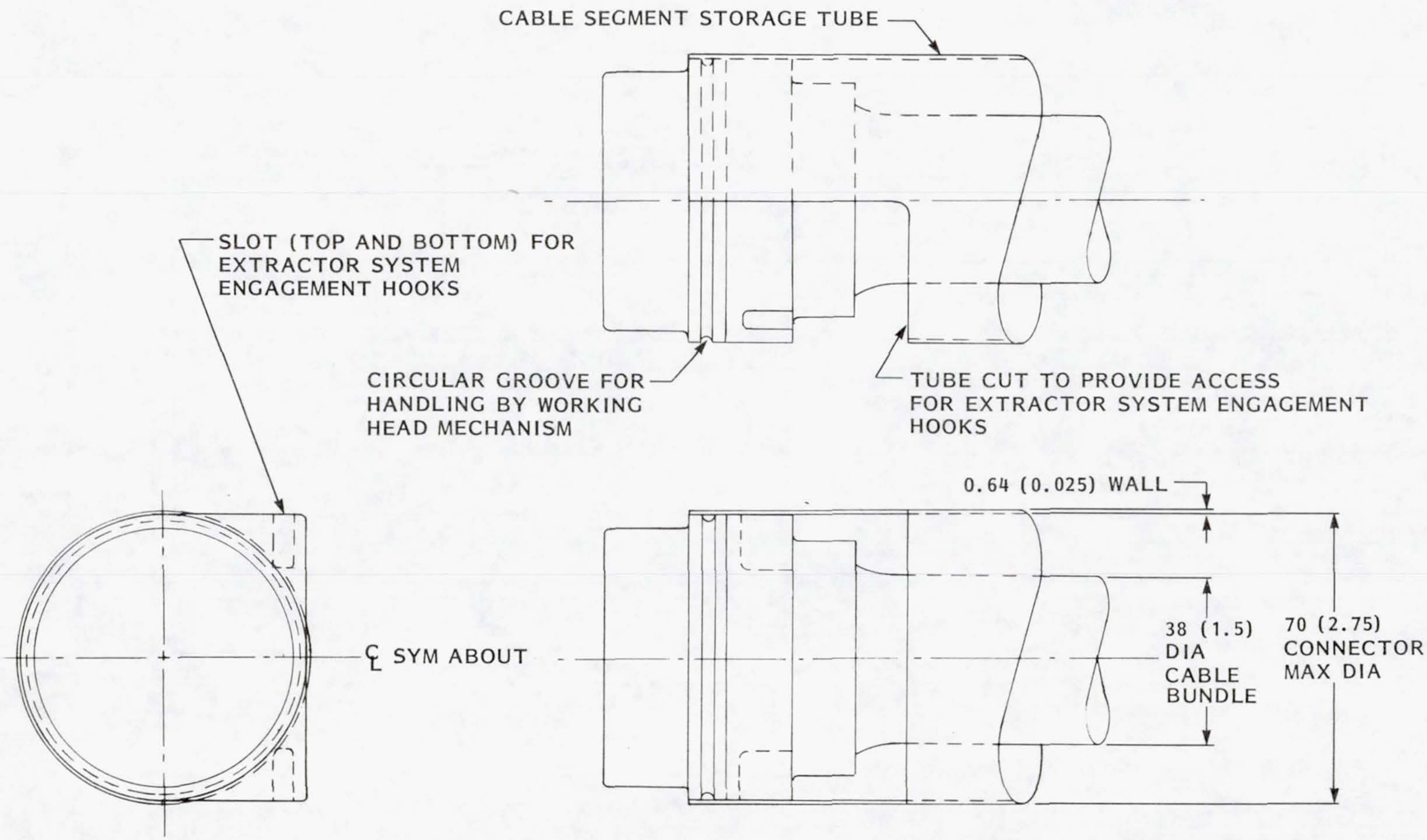

Figure B2 Electrical Cable/Connector Detail

APPENDIX C

Conceptual Design for Column Ejection from Canister

Each individual half column must be partially ejected from the canister to a position such that the working head mechanism* can capture the half column and then fully extract it from the canister. A conceptual design for ejection of the half columns from the canister is shown in Fig. C1. The figure also illustrates the design concept for placement of half-column stacks in readiness for individual half-column ejection.

In Fig. C1, the half-column stacks are shown packed in two tiers, each tier five stacks high. The tiers are loaded in the canister facing in opposite directions; i.e., head-to-tail. Tiers of more or less than five stacks can be used, but tier height is limited to approximately 7 m by the requirement for forward clearance for the vertical chain drive cross bars.

The bottom stack in each tier is supported in a small wheeled caisson at the closed (aft) end of the canister. Each caisson is driven forward in desired increments by means of a chain-driven, free-running sprocket mounted on the bottom of the caisson. Each caisson is individually driven (although a different vertical chain arrangement would permit linking of the pair of caissons). The caissons run in guide rails and each caisson's chain drive runs between a fixed drive sprocket at the end of the canister and a fixed idler sprocket near the end of the first half-column to be extracted. A drive shaft protrudes from the canister for connection of the drive sprocket to an externally mounted stepper motor for each caisson.

*The working head mechanism is described on page 54 of NASA CR 3131.

The caissons are not intended to provide ascent load support to the column stacks. Fore-and-aft (axial) ascent load support is provided to the stacks by the ends of the canister or fittings/receptacles mounted thereto. Lateral ascent load support is provided to the stacks at the aft end of the canister by the vertical chain drive cross-bars and by rail guides mounted on the ends of the canister (for the small-diameter end of the stacks) or by side stops mounted on the ends of the canister (for the large-diameter end of the stacks).

When the caissons have moved full stroke, the last half-column on each of the lower tiers is extracted and the caissons are then returned to their aft-most position by means of the sprocket, chain, and stepper motor drives. The lower tiers are then ready to be refilled.

Each stack in the vertical tiers is held in place by cross-bars through two triple chain drives. Cross-bar spacing on the drives is arranged to secure the 250 mm and the 50 mm dia stack ends in the proper relative vertical position. The second triple chain drive, located at the end of the first half-column to be ejected, provides mid-body support at 250-mm dia sections of both stacks. The vertical chain drive cross-bars support the half columns at locations where the bearing loads are taken by the column end fittings, rather than by the thin-walled column central section.

Each vertical chain drive is moved simultaneously in the desired increment by stepper motors mounted externally to the canister assembly. A drive shaft from one drive sprocket in each vertical chain assembly protrudes from both sides of the canister for connection to redundant stepper motors. Sequencing of the stepper motors actuates the vertical drive and lowers the half-column stacks into the caissons. In addition, the 50-mm dia forward end of one stack is guided and centered by a spring which deflects forward to permit extraction of the individual half columns. After the column stacks have been lowered into the caissons, the stack of large aft-end diameter is retained in its caisson by springs, while the stack of small aft-end diameter is retained by stepping the caisson forward until a lip rides over the top of the small diameter end.

With the lower tier refilled with half-column stacks, another cycle of horizontal ejection of each individual half-column in each of the tiers may then take place. The horizontal and vertical feed cycles continue until the canister half-column supply is exhausted.

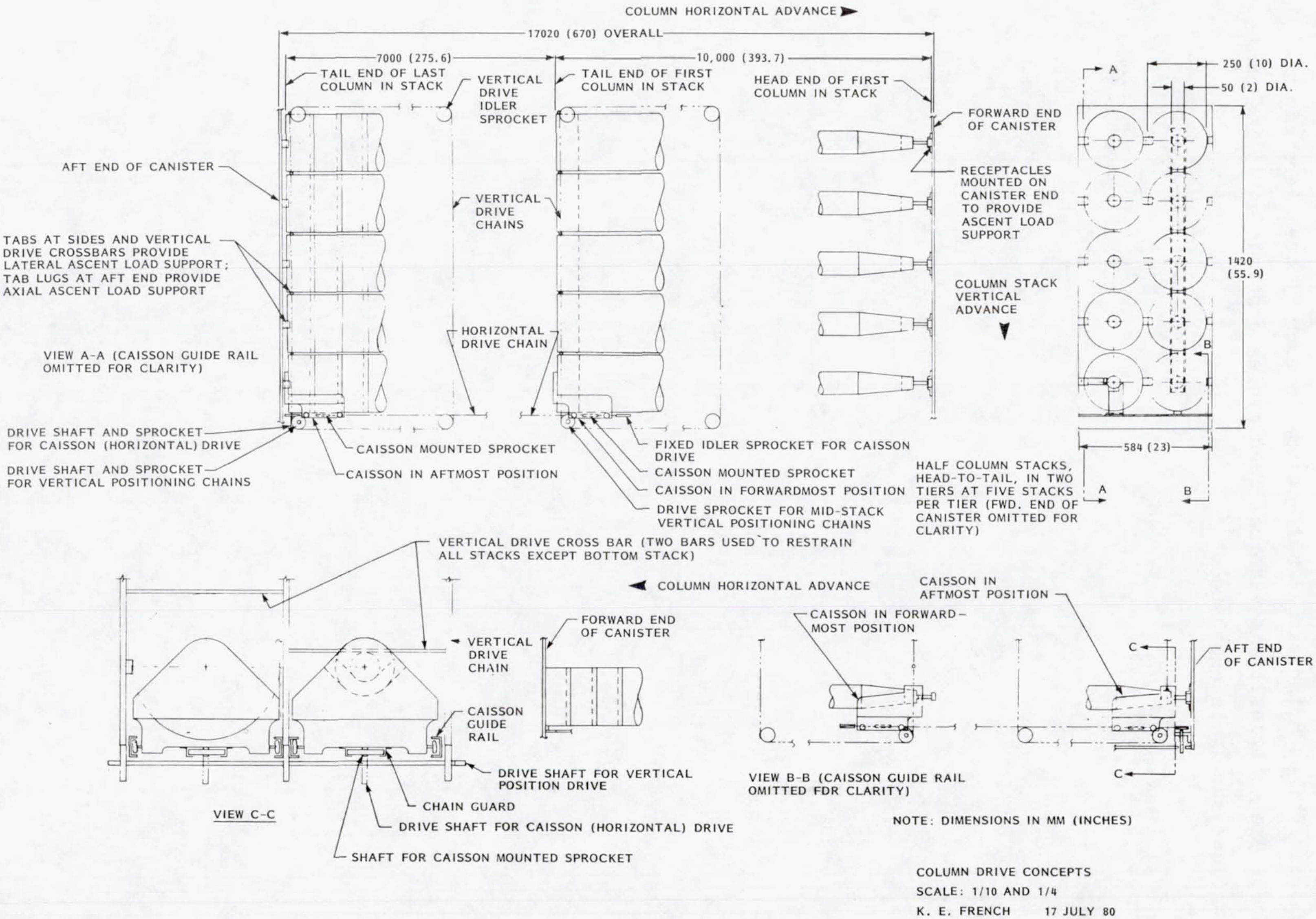

Figure C1 Column Drive Concepts

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-165681		

4. Title and Subtitle	5. Report Date
LARGE PLATFORM ASSEMBLER NON-STRUCTURAL SYSTEM REQUIREMENTS	April 1981
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Robert M. Vernon	LMSC/D760269
	10. Work Unit No.
9. Performing Organization Name and Address	
Lockheed Missiles and Space Company, Inc. 1111 Lockheed Way Sunnyvale, CA 94088	11. Contract or Grant No. NAS1-15240, Mod 6
	13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitors: Otis C. Childress and Harold G. Bush

Final Report

16. Abstract

This document summarizes a study which examined the impact on the design and operation of an automated structure assembler, of requiring the assembler to also install the platform electrical and/or fluid utility circuits. An initial definition of possible utility requirements was made. These requirements were examined in conjunction with the automated assembler reported in NASA CR-3131. Preliminary concepts are presented which permit the electrical and fluid circuits to be installed with the structural elements.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Large Space Structure, erectable automatic assembly, node joints orbiter packaging, utilities	Unclassified - Unlimited Subject Category 37

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	80	A05

N-305

*For sale by the National Technical Information Service, Springfield, Virginia 22161